Essays on Agricultural and Financial Markets in Pakistan

DISSERTATION

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Abstract

In the spirit of applied economics, my dissertation comprises three interdisciplinary and policy-oriented Chapters, broadly related to the fields of development economics, agricultural economics and financial accounting. Methodologically, I have utilized a wide array of methods including economic modeling, time-series econometrics, mathematical analysis and numerical simulations.

In the first Chapter, I extend the burgeoning literature examining the adverse effects of the industrial organization of the microfinance sector and competition for donor money on poverty alleviation to highlight problems with the existing structure of the microcredit markets. My model explains the stylized facts associated with the recent crisis in the microfinance sector of less developed countries. First, I establish that no information sharing between competing firms on defaulters is a suboptimal Nash equilibrium in competitive microcredit markets. Second, I formulate a simple model of strategic default to show that the probability of ex-post default increases with the number of competitors and lending volumes in a given microcredit market via dilution of the dynamic incentives of loan repayment. Thereafter, I use the seminal work of Stiglitz & Weiss (1981) to argue that in the presence of ex-ante adverse selection and strategic default, there exists a unique profit maximizing interest rate independent of lending levels. Based on these
findings we formulate a dynamic optimization problem to capture the objective functions of credit unconstrained and credit constrained lenders. The default rates in a symmetric Nash equilibrium are compared with default rates from the analogous social planner problem to prove that intra-firm competition results in inefficiently high default rates. Subsequently, I show that increasing flows of donor funds lead to even higher default rates regardless of lender types. Lastly, I analyze the location choices of lenders to show that competition among lenders leads to an over emphasis on urban areas at the cost of the exclusion of rural areas, resulting in financial exclusion of rural poor and sub-optimally high default rates in urban areas.

In the second Chapter, I study the underlying mechanisms behind price fluctuations in the Pakistan poultry sector. Currently, the industry is at the brink of a crisis due to persistent fluctuations. The paper makes several timely contributions to the literature. First, based on extensive fieldwork, we document the organization of production and the price discovery process in the poultry sector in Pakistan. Second, I develop a parsimonious, dynamic model to simultaneously capture the optimizing behavior of chick and poultry farmers. I explicitly model the mutual interdependencies between upstream farmers and downstream farmers arising from vertically linkages in agricultural values chains, an aspect of agricultural production overlooked in the theoretical literature on cobweb models. Third, empirically testable hypothesis about farmers’ expectation regime are derived from the underlying model as a system of linear time-delay difference equations. Estimations resulted based on a unique, hand-collected dataset comprising weekly farm-
gate prices of chicks and broilers in Pakistan reveal that the behavior of poultry prices is broadly consistent with a naïve expectation regime and hence cobweb cycles. Fourth, mathematical and numerical analysis are used to demonstrate that the underlying model reproduces the stylized patterns observed in the actual poultry prices, i.e., cyclical behavior, positive first order autocorrelation, negative kurtosis and randomness.

In the third and final Chapter, I examine the relationship between firm-specific accounting information and stock prices in the Karachi Stock Exchange (KSE). I use the information capitalization approach within the value relevance regression framework to motivate an empirical test of the hypothesis that growth in KSE was driven by market manipulation and devoid of economic reality. Estimation results clearly show that accounting information is an important determinant of stock prices and merit a reconsideration of the hypothesis that KSE is a ‘phantom’ stock market. However, time-series regressions reveal a gradual decline in the value relevance of accounting information that cannot be fully explained by the earning lack of timeliness hypothesis or changes in earnings quality. In light of macroeconomic developments and the prevalent institutional environment, I hypothesize that “noise trading” driven by herding behavior has led to the decline in the value relevance of accounting information in KSE. Empirical estimates from the Hwang & Salmon (2004) state space model lend support to this hypothesis. Lastly, the theoretical literature on asset price bubbles is used to formulate a simple econometric model to evaluate the impact of different macroeconomic factors on herding behavior. Estimation results reveal that increases in liquidity (expansionary
monetary policy) and foreign portfolio investment are key drivers of herding behavior in the KSE.
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Table of Contents

Abstract........................................................................................................................................ ii

Acknowledgments...................................................................................................................... vi

Vita........................................................................................................................................ viii

Table of Contents..................................................................................................................... ix

List of Tables ............................................................................................................................. xi

List of Figures ........................................................................................................................... xiii

Chapter 1-When More is Less: Suboptimal Equilibrium in Microcredit Markets in Less Developed Countries........................................................................................................... 1

Chapter 2-Endogenous Price Fluctuations in a Vertically Linked Agricultural Value Chain: A Simple Model and Empirical Evidence from the Pakistan Poultry Sector...... 107

Chapter 3-The Declining Value Relevance of Accounting Information and Herding Behavior: Empirical Evidence from an Emerging Stock Market .............................. 229

References.................................................................................................................................. 327

Appendix A: Proof of Proposition 2A in Chapter 1 ............................................................. 348

Appendix B: Derivation of Equation 3 in Chapter 1 ............................................................. 349

Appendix C: Derivation of Equation 4 in Chapter 1 ............................................................. 352
List of Tables

Table 1 Extent of Poverty in South Asia ................................................................. 14
Table 2 Payoff Matrix of Location Choice Game ....................................................... 95
Table 3 Production & Consumption of Poultry Chicken in Pakistan ......................... 117
Table 4 Summary Statistics for Broiler & Chick Prices ............................................. 126
Table 5 Time Series Properties of Poultry Price Data .............................................. 164
Table 6 Engle & Granger Cointegration Test ............................................................. 173
Table 7 Estimates from Restricted Model ................................................................. 175
Table 8 Estimates from Unrestricted Model ............................................................... 180
Table 9 Relevant Statistical Measures of Simulated Price Data .................................. 219
Table 10 Stock Price Data Summary Statistics ......................................................... 246
Table 11 Price Model Regressions .......................................................................... 249
Table 12 Return Model Regressions ........................................................................ 254
Table 13 Fixed Effect Regression Models with Controls for Losses ......................... 258
Table 14 Return Model Regression Results with Controls for Losses & Firm Size .... 261
Table 15 Return Model Year by Year Regressions .................................................... 262
Table 16 Earnings Quality-Estimates of Earnings Persistence & Smoothness ............. 268
Table 17 Earnings Lack of Timeliness Hypothesis .................................................... 276
Table 18 Summary Statistics: SD of OLS Betas ....................................................... 300
Table 19 Estimates of Herding Behavior from State Space Model................................. 301
Table 20 Decline in the Value Relevance of Accounting Information-Determinants.... 311
Table 21 Stationarity-Unit Root Tests ............................................................................ 315
Table 22 Macroeconomic Drivers of Herding Behavior ................................................. 317
List of Figures

Figure 1 Dynamic Incentives & Probability of Strategic Default........................................ 45
Figure 2 Interest Rates: The Price of a Loan and a Screening Device .............................. 54
Figure 3 Project Return Distributions of Good and Bad Types......................................... 55
Figure 4 Probability of Strategic Default for Good and Bad Types .................................. 58
Figure 5 Effect of Competition on Equilibrium Default Rates under Different Market Structures .......................................................................................................................... 78
Figure 6 Effect of Competition for Donor Funds on Equilibrium Default Rates ............... 87
Figure 7 Location Choice Game Tree ............................................................................... 97
Figure 8 Poultry Production Cycle .................................................................................. 123
Figure 9 Time Series Line Plots of Broiler & Chick Prices .............................................. 128
Figure 10 System Eigenvalues on Real-Imaginary Axis .................................................. 201
Figure 11 Simulated Prices-Linear Time Delay Models .................................................... 207
Figure 12 Simulated Prices-Non-Linear Time Delay Model .......................................... 209
Figure 13 Linear Time Delay Model Sensitive Dependence on Initial Conditions ......... 213
Figure 14 Bifurcation Diagram of Linear Time-Delay System ........................................ 216
Figure 15 KSE-100 Index 1999-2013 ............................................................................. 231
Figure 16 Decline in Value Relevance of Accounting Information ................................. 278
Figure 17 Evolution of Herding Behavior in KSE............................................................... 306
Figure 18 The Inverse Relationship between Herding Behavior & the Explanatory Power of Accounting Information .......................................................... 309
Chapter 1

When More is Less: Suboptimal Equilibrium in Microcredit Markets in Less Developed Countries

1 Introduction

Microfinance plays a key role in the poverty alleviation strategy of international development agencies and an array of donor funded microfinance institutions are increasingly the preferred option for microcredit interventions in less developed countries. As a result, the microfinance sector has witnessed exponential growth over the past two decades, especially in South Asia, Latin America, and Africa, where poverty rates are among the highest in the world. For instance, South Asia has a poverty headcount of 993 million people with poverty rates of up to 70.9%\(^1\) (World Bank 2008).

The emergence of microfinance in the 1990s was touted as “the” solution to endemic poverty in less developed countries. The appeal of microfinance lay in its simple yet powerful idea that the financially excluded poor can “work” themselves out of poverty by engaging in micro-entrepreneurship if given access to credit. Low rates of default on commercial microloans in Bangladesh recorded by the founder of microfinance, Professor Muhammad Yunus, gave further credence to this idea. While, related financial innovations (e.g. joint liability contracts, dynamic repayment incentives etc.) led many

\(^1\)Calculated as the poverty headcount ratio at $2 a day (PPP) as percentage of total population
economists to correctly believe that well known problems (i.e., adverse selection, moral hazard and strategic default) associated with lending in undeveloped financial markets were adequately mitigated. It seemed that microfinance ticked all the right boxes, i.e., intuitive appeal, theoretical foundations, and favorable empirical evidence. Unfortunately, no one knew at the time that all three were to be seriously disputed over the coming years.

In fact, the idea that access to microcredit would lead to economic growth was not new at all. From the 1950s-70s, development agencies aggressively supported and funded many public sector agricultural banks that provided heavily subsidized loans to the financially excluded, rural agricultural households (Robinson 2001). This emphasis was not unjustifiable, since subsistence agriculture was the primary source of livelihood for poverty stricken rural populations, usually comprising of 70-80% of the population in less developed countries. But the underlying idea was remarkably similar to contemporary microfinance, i.e., access to loans will allow credit constrained households to exploit profitable investment opportunities and over time these investments will pull clients out of poverty. Consequently, policy makers anticipated that investments in agricultural technology and cottage industry in rural areas, spurred by access to credit, would herald mechanization, capital accumulation and investment in human capital and would accelerate the structural transformation of poor agrarian countries into affluent industrialized economies.
However, the expected results were nowhere to be seen and by the 1980s policy makers reluctantly accepted that the idea had failed. Diagnostics revealed that due to wide scale corruption and politically motivated loan disbursements, credit did not reach the intended recipients, i.e., the rural poor, but was instead given to large, politically connected farmers. Poor management driven by bureaucratic apathy inevitably led to high administrative costs and low recovery rates, leading to the insolvency of several agricultural development banks. Hence, the time of targeted, subsidized rural credit as a panacea to poverty had finally come to an end. More importantly, this failure challenged the basic tenants of state interventions in markets and called for a more market driven approach to economic development. Thus minimalist state intervention in markets became the new mantra of the time.

The success of commercial microfinance in the 1990s and emergence of related financial innovations also seemed to fit perfectly with the rise of the neo-liberal ideology of economic growth, which was imbued with a renewed faith in market mechanisms after the dissolution of the Soviet Union in 1991. And financial sector growth driven by financial engineering was considered to be a prerequisite of growth in the real sector. The rise of the neo-liberal ideology of economic growth along with the previous failure of public sector rural agricultural banks paved the way for the so-called “microfinance revolution”.

3
The microfinance revolution called for complete paradigm shift from the earlier, largely unsuccessful poverty lending approach of the 1950s-70s, which promoted subsidized credit for the rural poor, to a financial systems approach (Robinson 2001). In the true spirit of capitalism, the financial systems approach encouraged market based micro credit interventions, sugarcoated with the alluring slogan of a double bottom line, whereby higher profits would lead to more poverty alleviation. The idea of profitable poverty alleviation was supported by developments in other fields, succinctly captured in the title of the influential book “The Fortune at the Bottom of the Pyramid: Eradicating Poverty through Profits” by well-known business thinker C.K. Prahalad. And alas, backed by neoliberal ideology, alluring slogans and (non-scientific) anecdotal evidence, another magic bullet was born!

Since, the microfinance bullet was destined to wipe out poverty for good, just like its numerous predecessors (e.g., aid for infrastructure development, subsidized rural credit, structural reform, etc.), the next logical step was to scale-up the microfinance whilst improving the efficiency of the sector. However, this time, in line with standard policy prescriptions of the neoliberal economic growth ideology, scale and efficiency were to be achieved via market mechanisms, whereby entry of profit motivated firms into the sector would not only lead to a larger supply of loanable funds but the ensuing competition among lenders would result in higher efficiency, transpiring into greater poverty alleviation.
Interestingly, in contradiction to the true spirit of market based economics, in order to promote the financial systems approach, large sums of donor money were pumped into the commercial microfinance sector in the form of subsidized debt, soft loans, technical-assistance grants and in some cases simple giveaways. For instance, Viada and Gaul (2011) documented that donors committed $800 million to $1 billion to microfinance per year on average. The underlying logic was that commercial microfinance needed to be subsidized until it reached a scale at which profitable lending would be feasible. But in reality, the microfinance revolution had essentially chosen to subsidize commercial microfinance institutions over poverty stricken borrowers.

To summarize, the microfinance revolution emphasized market driven mechanisms based on the slogan of double bottom line as the best solution to poverty alleviation in less developed countries. Competition in the private sector was assumed to create the right incentives for improved outreach and efficiency. Therefore, both local and international donors readily agreed to pump money into the sector to help the microfinance revolution achieve its goal, i.e., poverty alleviation, through large-scale profitable provision of microfinance services. Consequently, by a UN resolution, 2005 was marked as the year of microfinance and Professor Yunus was honored with the Nobel Peace Prize.

Nevertheless, several economists (e.g., Murdoch 2000) and practitioners (e.g., Dichter 1996) saw the writing on the wall, even during the heyday of microfinance in the early 2000s. In particular, Murdoch (1999a) showed that Grameen bank, the shining star of the
microfinance revolution, was actually not commercially viable after adjusting for donor subsidies and giveaways. And the story was pretty similar for other well-known commercial microfinance institutions (Murdoch 1999b and Conning & Murdoch 2011). Likewise, Dichter and Harper (2007) along with many other practitioners highlighted several internal contradictions inherent to the microfinance revolution. Unsurprisingly, the microfinance “bandwagon” pushed forward unfettered by “academic” criticisms or “philosophical” moral dilemmas under the pretext that the microfinance sector still needed more resources and time to fulfill its promise. But unfortunately, some times, more is actually less!

Fast forwarding 10 years to 2016, despite the backing of billions of dollars in financial assistance and organizational support of different developmental agencies, the microfinance revolution has failed to deliver on its promise of profitable poverty alleviation (Conning & Murdoch 2011, Weiss & Montgomery 2005 & Murdoch 1999b). In fact, significant improvements in measures of competitiveness and funding have actually had the opposite effect on performance measures. And the microfinance sector has been rocked by several repayment crises over the past few years in less developed countries across the world, e.g., India (Duflo and Walton 2007, Sriram 2010, Ghosh 2013 and Mader 2013), Bolivia (Vogelgesang 2003), Morocco (Chen et al. 2010), Pakistan (Burki 2009), Bosnia (Chen et al. 2010) and Nicaragua (Bastiaensen et al. 2013) etc. The microfinance sectors in Bangladesh and South America, the pioneers of the microfinance revolution, have not fared much better either. Grameen bank has been pegged back by
scandals of corruption and embezzlement, and rising default rates. While, with rising loan balances, many large micro lenders in South America have failed to remain true to their original mission, i.e., providing access to credit to the poor, and have instead slowly drifted towards serving the lower middle class by becoming small retail banks, or what some would call “glorified payday loan shops”, undermining the original purpose of subsidies.

More importantly, rigorous empirical work based on randomized control trials (Augsburg et al. 2012, Banerjee et al. 2013, Crépon et al. 2014 and Angelucci et al. 2015) has suggested that earlier studies exaggerated the impact of microfinance on poverty alleviation and has raised doubts over whether microfinance has a positive impact on poverty alleviation in the first place. Nonetheless, despite the lack of clarity on the impact of microcredit on poverty and frequent repayment crises, microcredit continues to play a dominant role in the poverty alleviation strategy of development agencies and governments. For example, the Bill and Melinda Gates Foundation announced a $500 million initiative called “Financial Services for the Poor” with an objective of improving accessibility of microfinance services for poor people in the less developed world. Likewise, the State Bank of Pakistan has implemented several polices over the past few years to promote commercial microfinance in Pakistan. Part of the resilience of microfinance to the abovementioned setbacks is driven by the alluring appeal of commercial microcredit, which combines the warm glow effect of charity with the
dynamism of market based capitalism (Dichter 2010). The other part is evidently driven by the naivety of its supporters.

In light of abovementioned context, we focus on the supply side dynamics of the microfinance industry in this paper. Our primary objective is to elucidate the mechanisms that have resulted in frequent repayment crises that have plagued the microfinance sector in less developed countries over the past few years. In particular, we are interested in addressing why repayment rates have plummeted after a period of steady growth, despite improvements in competitiveness and availability of funding? Of course, we are not the first ones to be interested in these questions and a burgeoning literature examining the effects of the industrial organization of the development sector on poverty alleviation has emerged over the past decade (Ghosh & Tassel 2013; Guha & Chowdhury 2013; Roy & Chowdhury 2009; McIntosh & Wydick 2005, McIntosh et al. 2005, Fruttero & Gauri 2005 and Aldashev & Verdier 2010).

We provide a brief overview of this literature to highlight the nature of our contribution in the next Section. But, very briefly, we extend this stream of literature by focusing on the strategic interaction among lenders to highlight the adverse effects of different forms of intra-firm competition on repayment rates. To this end, we try to integrate existing research on the effects of the organization of the microfinance sector on poverty alleviation (Guha & Chowdhury 2013 and McIntosh & Wydick 2005) with the literature looking at the consequences of competition among NGOs for donor money (Rose-
Ackerman 1982, Castaneda et al. 2007 and Aldashev & Verdier 2010). The main conclusion of our analysis is that intra-firm competition among lenders can result in inefficiently high default rates in urban markets (where transaction costs are assumed to be lower compared to rural areas) and exclusion of rural markets from access to credit, undermining the original goals of microfinance revolution, i.e., sustainable lending and financial inclusion. Moreover, increasing inflows of donor money only exacerbate the problems associated with intra-firm competition.

Intuitively, these results are based on the simple yet powerful idea that microfinance institutions have a private supply curve of “poverty alleviation effort” that does not account for the positive externalities of serving financially excluded microcredit markets. Likewise, in the absence of information sharing on defaulters in equilibrium, the private supply curve of “poverty alleviation effort” also does not account for the negative externality imposed on competing lenders from higher lending volumes, resulting in inefficiently high default rates and overconcentration in urban markets. Empirical research (McIntosh et al. 2005, Fruttero & Gauri 2005 and Assef et al. 2013) and case studies on recent microfinance crises (Duflo and Walton 2007, Burki 2009 and Chen et al. 2010) lend support to our findings.

Our findings have important policy implications. Contrary to popular belief, increasing levels of competition and access to funding are actually not optimal in the institutional environment prevalent in less developed countries. But in fact adverse incentives created
by private provision of microfinance services results in the same market failures that microfinance were originally designed to overcome, undermining the rationale for subsidizing microfinance in the first place. In order to overcome these problems we recommend a return towards public sector provision of microcredit, despite its failures in the past.

We have organized the paper as follows. In Section 2 we describe some distinctive features of microcredit markets in less developed countries and dissect the anatomy of recent microfinance crisis to highlight key mechanisms behind falling repayment rates. This is followed by a brief overview of the theoretical and empirical literature to draw attention towards the nexus between the organization of the microfinance sector and poverty alleviation. In Section 3, we establish that no information sharing on defaulters among competing lenders is the sub-optimal equilibrium in microcredit markets in less developed countries. Thereafter, in order to trace the implications of this equilibrium outcome on the demand side, i.e., borrower’s behavior, we develop and analyze a simple model of strategic default. Building on Section 3, Section 4 characterizes the equilibrium default rates in different market structures under the cooperative and non-cooperative solution. The adverse effects of increasing donor inflows on default rates and the location choices of different types of lenders are studied in Section 5. Finally in Section 6, we provide a summary of key findings and offer some policy recommendations.
2 Literature Review: Microfinance in Less Developed Countries-Important Issues, Stylized Facts and Repayment Crisis

As mentioned before, the exponential growth of microcredit rested upon the assumption that access to credit leads to higher incomes and eventually poverty alleviation. The impact of microcredit is an empirical question. Therefore, before proceeding further, we need to arrive at a reasonable conclusion vis-à-vis the impact of microfinance on poverty alleviation.

The influential work of Pitt and Khandker (1998), suggested that that approximately 5% of households were pulled out of poverty due to microcredit in Bangladesh and there was 10.5% to 18% increase in the consumption levels of microfinance clients compared to non-clients. But some economists, notably Roodman and Morduch (2014) challenged their empirical strategy and showed that their estimates were positively biased due to the presence of outliers and self-selection bias. Nevertheless, the positive impact of microfinance on poverty alleviation has been subsequently documented by later research (Imai et al. 2012, Chemin 2008, Mosley & Hulme 1998), albeit to varying extents. The recent emergence of randomized controlled trials in economics promised to resolve the self-selection bias controversy. And early work based on randomized controlled trials has suggested that microcredit has no discernable impact on client income, health, education or women empowerment (Augsburg et al. 2012, Banerjee et al. 2013, Crépon et al. 2014 and Angelucci et al. 2015). However, evidence from randomized control trials is scant at
best and hopefully answers to questions about the impact of microcredit will become
clearer with more experimental studies in the future.

In this paper we take the impact of microfinance as given, although admittedly it remains
a contested area. But in our view the impact of microcredit is dependent upon the client’s
repayment capacity, which arises from the existence of viable production opportunities. If
clients have repayment capacity, then access to credit will generate additional income
resulting in poverty alleviation. However, if clients do not have repayment capacity, then
clients will eventually default on microloans, leading to long run impoverishment as
physical and social collateral decays. Of course, if a large number of clients default then
the microfinance institution is also rendered insolvent, and the whole community is
impoverished as a result. Therefore, repayment capacity is the key determinant of the
success of microfinance and may also explain why microfinance has failed in some
environments but succeeded in others (Imai et al. 2012).

Given the supply side focus of this paper, we assume throughout that clients possess the
necessary repayment capacity such that existing projects have the potential to generate
additional income whilst covering loan repayment. Therefore, we take the repayment
capacity of clients as exogenously determined by the macroeconomic environment and
initial conditions. This assumption helps us focus on the effects of supply side dynamics
on repayment behavior and determine under what supply-side conditions does

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2 This does not imply that, in a given microcredit market, the repayment capacity or quality of projects is
uniform across all potential clients.
microcredit flourish or vice versa. However, in reality, the success or failure of microfinance is obviously determined by the interaction of both supply and demand side factors.

Lastly, since money is fungible, apart from additional income, microcredit offers other benefits to clients, e.g., reduction in income volatility and disaster insurance. Of course, these additional benefits imply that households simply consume microloans as a source of additional liquidity when faced with adverse shocks. This may also explain why the poor are willing to pay exorbitantly high interest rates on microloans, because, given a concave period utility, the marginal utility from additional consumption can be extremely high at very low levels of consumption. But consumption of investment loans is inefficient in the long run and problematic for lenders in the absence of collateral, although, additional liquidity in times of need has a positive impact on a client’s health and education outcomes in the short run. We do not incorporate issues related to the consumption of loans in our paper, because its impact on default rates is well known. And the effects of competitive pressures in the microfinance industry on the consumption of microloans are extensively examined in Guha and Chowdhury (2013).

2.1 Key Features of Microfinance in Less Developed Countries

Undoubtedly, overcoming poverty is arguably the biggest challenge of the 21st century. Despite decades of policy interventions and billions of dollars in financial aid, the breadth and depth of poverty continues to be a major concern in less developed countries, as an
estimated 2.6 billion people live on less than $2 a day, 1.4 billion of whom are extremely poor and survive on less than $1.25 a day (Chen & Ravallion 2008). Particularly high levels of poverty are present in South Asian countries, which are also beset by rising populations, low per capita incomes and rural-urban inequalities. Table 1 depicts poverty levels in Bangladesh, Pakistan and India:

Table 1 Extent of Poverty in South Asia

<table>
<thead>
<tr>
<th></th>
<th>Population</th>
<th>GNI per Capita($)</th>
<th>Poverty Headcount at &lt;$2</th>
<th>Agriculture as % of GDP</th>
<th>GDP Growth</th>
<th>% of Rural Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangladesh</td>
<td>150,500,000</td>
<td>780</td>
<td>76.5%</td>
<td>18%</td>
<td>7%</td>
<td>72%</td>
</tr>
<tr>
<td>India</td>
<td>1,241,000,000</td>
<td>1,410</td>
<td>60.2%</td>
<td>17%</td>
<td>7%</td>
<td>69%</td>
</tr>
<tr>
<td>Pakistan</td>
<td>176,700,000</td>
<td>1,120</td>
<td>68.7%</td>
<td>22%</td>
<td>3%</td>
<td>64%</td>
</tr>
</tbody>
</table>

Source: World Bank 2011 Database

Table 1 highlights large populations, poverty rates in excess of 60% and a positive correlation between rural population and poverty. Of course, in addition to statistical measures, poverty is also associated with a lack of access to basic services including credit. And there are a very few sources of credit for the poor despite the high demand for it.

What do these massive poverty levels mean for microfinance? In one word, credit rationing. Because demand for credit simply outstrips the size of loanable funds, many

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3 The data for 2011 was unavailable; this refers to 2010 figures for Bangladesh and India, and 2008 figures for Pakistan, all retrieved from the World Bank database.
loan applicants are denied access to credit even though they are willing to pay the quoted interest rates. For instance, back of the envelope calculations based on Table 1 reveal that with an average loan size of $100 per client, lending reserves of approximately 100 billion dollars are needed to fulfill demand for microloans in these countries. Practically speaking, in physical terms, the microfinance sector may never reach this scale in South Asia. And as we show later, simply pumping additional money into the sector also does not solve the problem. We return to issues related to excess demand, interest rates and credit rationing in the context of financial markets in Section 4.1.

An inherently poor institutional environment is another important feature of less developed countries. Consequently, existing information asymmetry problems in financial markets are compounded by several institutional voids, e.g., absence of functioning credit bureaus, lack of proper identification documents and weak contract enforcement mechanisms. Hoff and Stiglitz (1990) have emphasized the importance of contract enforcement problems in the credit markets of less developed countries, whereby it is difficult to compel loan repayment in weak institutional environments, leading to higher likelihood of ex-post default. The stylized facts associated with the microfinance crises also highlights that in most cases clients “rationally” default on loan obligations despite possessing the ability to repay, often in full cognizance of meager default penalties. It is for these reasons that we choose to focus on the relationship between competitive pressures and ex-post moral hazard or strategic default in the microfinance

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4 For example, absence of proper identification documents and credit bureaus, exacerbate client screening problems.
industry in our paper, an area that has not been fully examined in the existing literature to best of our knowledge.

Important organizational characteristics of the microfinance sector like market structure, complexity of business operations, type of funding and distribution of branch network etc., vary from one country to another based on a myriad factors including level of development of the microfinance sector, geographical economic disparities and cost of doing business. Nevertheless, the microfinance sectors in less developed countries also share several common features. First, consistent with the paradigm shift in the microfinance sector, lending volumes in the sector have become increasingly dominated by profit-based lenders over the last decade. But as mentioned before, very few for-profit microcredit lenders actually make a profit and thus rely on injections of donor money and subsidies to stay afloat. The microfinance sector in less developed countries is also characterized by negligible deposit base, resulting in an over reliance on donor funds in nascent markets like Pakistan, Nicaragua, Uganda, Bosnia etc. or commercial debt in mature markets like India, Bolivia and Bangladesh etc. In the case of the former, competition for donor funds introduces another channel of strategic dependence between competing lenders.

Second, the microfinance sector in most developing countries is based on a simple business model that primarily offers a standardized microcredit product. Therefore, in our paper we look at pooling equilibrium by assuming that lenders offer a homogenous
contract to all clients. This minimalist approach keeps operating costs low, but offers a
standardized loan contract that also limits the set of feasible growth strategies (Sriram
2010). Consequently, many lenders opt for an extensive growth strategy, i.e., increasing
the number of borrowers (outreach) as opposed to an intensive growth strategy, i.e.,
expanding the portfolio of financial product. Of course the lack of differentiation in the
sector also implies that borrowers can readily switch between lenders, since credit
contracts offered by competitors are similar if not identical. In the absence of information
sharing on defaulters, the lack of differentiation also erodes dynamic repayment
incentives, increasing the likelihood of ex-post default. In more developed microcredit
markets especially in South America, lenders use different contract designs as an indirect
mechanism to screen clients, issues related to separating equilibrium and competition
among lenders in these markets are the subject of Casini (2015) and Navajas et al. (2003)
and not pursued herein.

Third, over the past few years a large influx of lenders in the microfinance sector in less
developed countries has challenged the local monopolies that first movers (e.g., Grameen
in Bangladesh, Kashf in Pakistan and Bhartiya Samruddhi Finance in India) enjoyed
during the early 2000s. Due to the presence of several lenders, microcredit markets can
be classified as competitive in nature. But development of a supporting institutional
environment has not kept pace with the increasing levels of competitiveness. Anecdotal
evidence from several countries including Pakistan (Burki & Shah 2007), Uganda
(McIntosh et al. 2005) and India (Ghosh 2013), suggests that information sharing on
defaulters among competing lenders does not take place. We examine these developments along with the effect of increasing competitiveness on repayments rates in the absence of information sharing on defaulters in Section 3.

Lastly, the distribution of microcredit markets is becoming increasingly asymmetric and is generally biased towards urban and peri-urban areas in less developed countries. Consequently, some urban areas have witnessed an almost 10-fold increase in borrowers, often driven by multiple borrowing or double-dipping by clients (Burki 2009 and Chen et al. 2010). On the other hand, lending volumes in rural areas, where the transaction costs of delivering credit are usually higher compared to urban areas, have witnessed no change or in some cases even declined. This has resulted in a largely segmented market distribution (i.e., congested urban areas and largely vacant rural areas), although individual markets are fairly homogenous in terms of loan demand and repayment capacity. Interestingly, the schism between rural and urban lending has been more pronounced in countries where the microfinance sector is driven by donor funded micro-credit interventions (Chen et al. 2010). We use simple game theoretic arguments to address the location choice dilemmas of lenders in Section 5.2.

In summary, microcredit markets in less developed countries (LDCs) are usually characterized by the following institutional features. First, excess demand for microcredit along with the relatively limited size of industry loan reserves results in credit rationing.

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5 Bangladesh and to an extent India are expectations to this trend.
Second, the sector is fairly nascent in most less developed countries and dependent on donor funds. Moreover, lenders generally offer standardized loan contracts due to the high administrative costs associated with writing and managing credit contracts that force borrowers to self-select into different contracts by their types. Third, for-profit lenders increasingly dominate the industry and intra-firm competition has risen sharply over the past few years. Lastly, over time lenders largely operate in concentrated urban regions without systematic information sharing mechanisms about defaulters, and rural areas are increasingly marginalized from access to microcredit.

2.2 The Anatomy of Recent Microfinance Crisis and Overview of Literature

The global microfinance sector has been plagued by several major repayment crises over the past few years. Although the factors leading to a crisis differ on a case to case basis, Chen et al. (2010) in a report commissioned by CGAP documented common driving factors behind the microfinance crisis in Pakistan, Morocco, Bosnia & Herzegovina, Nicaragua. First, they find that repayment crises were often preceded by periods of high industry growth, which was primarily fueled by abundant funding from donors and social investors; e.g., cross-border investments in microfinance reached US$10 billion by 2008, almost a seven-fold increase over previous five years. Second, they find that growth was driven by shallow client-lender credit relationships often based on simple credit contracts in existing markets, giving rise to concentrated market competition that diminished dynamic repayment incentives and often led to multiple borrowing. Third, they find that incentives to increase outreach quickly or “credit push” led to the erosion of lending
disciplines. Interestingly, Chen et al. (2010) also find that external shocks like the global financial crisis were not major drivers of high default rates and in almost all cases the crisis was a story of strategic default or ex-post moral hazard. In summary, their analysis indicates that the soaring default rates were driven by increases in competition, i.e., more resources and more players, weak institutional environment and excessive concentration in a few markets.

The well-known Indian repayment crisis of 2010 in Andhra Pradesh confirms the abovementioned mechanisms. For example, the microfinance sector enjoyed a strong presence in Andhra Pradesh and many lenders flocked to the fertile Andhra Pradesh market in hope of securing additional funding from donors and investors. Consistent with the financial systems approach, many existing NGOs converted into non-banking finance companies and for-profit finance companies to better serve the huge demand for credit from a largely unbanked local population. A strategy of extensive growth led to an exponential increase in lending volumes and the number of borrowers increased from 10,000 in 2000 to approximately 15 million by 2008. However, with increasing competitive pressures, cracks started to appear. For example, competition for increasing market share led to erosion of lending disciplines on one hand and encouraged strategic behavior by borrowers on the other hand. Lack of information sharing on defaulters meant that clients started to take out loans from multiple lenders and indulge in consumption goods, whilst defaulting on previous loan obligations.
In wake of a series of suicides by microfinance clients in October 2010, largely blamed on coercive loan collection methods employed by lenders, the government intervened and effectively sealed the microfinance sector. At the same time to gain political mileage local politicians got involved and advised villagers not to repay loans. Consequently, repayment rates came down from a reported 97% to less than 30% in matter of a few weeks and lenders suffered massive erosion of lending reserves. Note that these losses were not driven by adverse macro-economic shocks or any change in the repayment capacity of clients. Given the size of the Indian microfinance sector, the crises set ripple waves around the global development sector and called for rethink and introspection on where the so-called microfinance revolution failed.

Like Chen et al. (2010), Quidt et al. (2012) and several others economists (Duflo and Walton 2007, Ghosh 2013 and Mader 2013 etc.) blamed the Indian crisis on the weakening of repayment incentives caused by increasing levels of competitiveness, lender’s obsession with portfolio volumes, spatial concentration of lending activities and shallow client-lender relationships usually based on a simple credit contract. These trends were exacerbated by the lack of supporting infrastructure, in particular functioning credit bureaus, encouraging double-dipping and strategic default by clients. The Indian microfinance crisis is an extreme example of the potential ramifications of increasing levels of competitiveness in the absence of a supporting institutional environment.
Although, less acute, the current developments in Pakistan microfinance sector highlight other interesting issues and mechanisms. The microfinance industry in Pakistan, the world 6th populous country, is fairly nascent with a history of roughly a decade. In the recent past, access to donor funds in Pakistan has fueled the exponential growth of a wide array non-profit NGOs offering microcredit services. Consequently their market share in the industry has risen from 26% in 2006 to approximately 36% in 2012.

But several policy papers highlight the increasingly uneven geographic distribution of microfinance providers between rural and urban areas and show that micro-credit NGOs are concentrated in the large cities and (Oxford Policy Management 2006; International Finance Corporation & KfWBankengruppe 2009). For instance, from 2005 to 2011 the percentage of active borrowers in the microfinance sector that are rural clients declined from 69% to 46%. The tendency of micro-credit NGOs to cluster around metropolitan centers at the expense of servicing the rural areas, where the extent and depth of poverty is higher, is clearly a type of “mission drift” in the case of altruistic lenders. Interestingly, as we show in Section 5.2, these rural-urban schisms are actually driven by competition for donor funds among non-profit organizations. Moreover, at the same time practitioners are complaining about increasing loan write-offs due to multiple borrowing by clients in congested urban centers, resulting in over indebtedness of clients and eventual default. And in 2012, the percentage of portfolio at risk in the micro-credit NGO category reached 10.2% compared to only 0.8% in 2006 (Pakistan Microfinance Network Industry Review 2012). Note that these trends were not observable in the Indian microfinance
crisis, which was primarily fueled by intra-firm competition among for-profit lenders. But in Section 5, we highlight that similar crises can materialize due to intra-firm competition for donor funds among non-profits, whereby increasing competition among MFIs for higher levels of donor money leads to concentrated credit markets and “credit push”, eventually leading to wide scale default similar to the microcredit crisis experienced in India.

Mechanisms highlighted in the above-mentioned case-studies elucidate the anatomy of microfinance crises in less developed countries. In summary, willingness to repay is drastically reduced by the interaction of weak institutional environments and competitive landscapes, making default attractive despite the possessing the ability to repay. And likelihood of microfinance crises is positively correlated with different measures of intra-firm competition and access to funding resources, donor money or otherwise. Given that information sharing among lenders on defaulters does not take place, insufficient screening due competitive pressures results in poor client selection. Finally, the “credit-push” encourages clients to act strategically by borrowing from multiple lenders or willingly defaulting on existing loan obligations.

Researchers have employed a wide variety of methods including economic modeling, statistical methods, quasi-experiments and careful description to study the underlying causes and mechanisms behind the abovementioned crises. An exhaustive survey of
theoretical and empirical research on these issues is clearly beyond the scope of this paper and instead we only draw attention to some major contributions.

There is a large theoretical literature examining the effects of the industrial organization of microfinance sector on poverty alleviation. The contended issue in this stream of literature is to determine the effects of different organizational structure and competitive pressures on the ability of microfinance to achieve its objectives, i.e., poverty alleviation and outreach in a sustainable manner. Most papers show that competition proves detrimental to some or all of the borrowers in a microfinance markets. Mcintosh & Wydick (2005) were among the earliest researchers to look at the adverse effects of competition on borrowers and proved that competition among incumbent monopolist and client maximizing microfinance institution exacerbates information asymmetry problems, imposing a negative externality on all borrowers, especially the poorest ones. They also proved that in competitive markets the extent and nature of grant funding, not the motivation of lenders, matters most; hence profit-maximizers and client-maximizers behave identically. However, they were not concerned with intra-firm competition and primarily relied on cross subsidization to drive their results. But, in our view, their assumption that client endowments can be observed by lenders is not realistic in light of the institutional environment prevalent in less developed countries.

Guha & Chowdhury (2013) use the Salop circular city model with socially motivated microfinance institutions to prove that competition in the microfinance sector leads to
double-dipping equilibrium, i.e., some clients engage in borrowing from multiple lenders. In particular, they demonstrate that increases in competition among lenders necessarily results in an increase in overall defaults rates via the double dipping channel and may even lead to higher interest rates if donor funding or subsides attract new entrants into existing microcredit markets. They also show that the double-dipping equilibrium is inefficient because it involves consumption. Although our conclusions are similar to Guha & Chowdhury (2013), we look at a different mechanism as clients cannot borrow from multiple lenders in our model. Moreover, focusing on socially motivated lenders seems problematic given the abovementioned paradigm shift from a poverty lending approach to a financial system approach in contemporary microfinance.

Interestingly, in contrast to McIntosh & Wydick (2005) and Guha & Chowdhury (2013), Boyd and De Nicoló (2005) prove that if both the deposit and loan market are allowed to respond to changes in competition, then greater competition actually leads to higher deposit rates and lower loan rates in the banking industry, leading to a Pareto optimal increase in the supply of loans and a decrease in default rates. Therefore, the effect of competition on borrower defaults is not clear-cut and actually depends on the prevalent institutional settings.

In contrast to the burgeoning literature on competition and poverty alleviations, existing research on the strategic interactions between lenders and donors is limited. Ghosh and Tassel (2011) find that because lenders are only concerned about their own impact on
poverty, it is optimal for altruistic donors concerned with maximizing poverty alleviation working in an environment of asymmetric information to charge a rate of return on donated funds in order to drive inefficient lenders out of the market. In non-microfinance settings, Aldashev & Verdier (2010) prove that competition for donor funds among differentiated NGOs is potentially inefficient due to the diversion of resources from project related activities to fundraising activities. Moreover, with a fixed level of donor funding, entry of each additional NGO into the development sector imposes a negative externality on all other competing NGOs by reducing the return on their fund-raising efforts. Rose-Ackerman (1982) arrives at similar conclusions while examining the effects of competition for funds among charities. All these studies emphasize the failure of individual microfinance lenders or NGOs to account for the negative externalities that their poverty alleviation effort imposes on other competing participants. We incorporate this stream of literature into our paper by looking at the strategic interdependence created by competition for donor funds based on relative outreach in the microfinance sector.

Despite the plethora of theoretical research, empirical work on these subjects is scant. In a recent study based on a large dataset comprising of 362 microfinance institutions across 73 countries, Assefa et al. (2013), find that increasing levels of competition during 1995-2008 was negatively associated with repayment performance. McIntosh et al. (2005) find that rising competition led to a decline in repayment performance in Uganda, primarily driven by lack of information sharing among competing lenders and a tendency of clients to borrow from multiple lenders. In an interesting application of theory and empirics,
Fruttero & Gauri (2005) find that NGO location choices for developmental projects in Bangladesh are driven by organizational concerns or a desire to secure additional donor funding as opposed to considerations for the needs of recipient communities. Their research clearly highlights that NGOs are not passive executors of development policy but act as economic agents interacting with donors, clients and competitors to maximize an objective function in which social welfare is just one of myriad arguments.

In light of findings from the previous literature and the institutional environment prevalent in less developed countries, we develop a simple model to explain the stylized facts associated with the abovementioned microfinance crises. In doing so, we explicate new mechanisms and channels behind the positive relationship between defaults rates and different measures of competition in the microfinance sector in less developed countries. In following Section we first show that due to public good nature of information sharing mechanisms, no information sharing on defaulters among lenders takes place. Thereafter, we use a strategic default model to show that measures of competition (extensive and intensive) dilute dynamics repayment incentives, leading to higher probability of default. In order to focus on supply side dynamics, we rely on the seminal work of Stiglitz & Weiss (1981) to make some justifiable simplifications on the demand side. Thereafter, we use non-cooperative game theory to examine the adverse effects of intra-firm competition on default rates under different market scenarios. Lastly, we illustrate how rising inflows of donor exacerbate repayment problems and create incentives for lenders concentrate on
densely populated, cheap urban markets at the expense of more costly rural markets. Our findings are supported by the relevant theoretical and empirical literature.

3 The Good, the Bad and the Ugly: Dynamic Incentives, Competition & Strategic Default

We begin this Section by formulating a simple model to show that no information sharing on defaulters takes place among microfinance institutions in equilibrium. Thereafter, we use a stylized strategic default model to highlight the adverse effects of this equilibrium outcome on the strategic behavior of borrowers.

3.1 Setup

At the start of each period, a given microfinance institution receives several applications for microloans. All applications are virtually identical except for information associated with the repayment history of each applicant. The repayment history includes private and non-private information pertaining to the repayment record of each applicant in previous periods. Private information alludes to the repayment record of an applicant held by a given microfinance institution in previous periods, e.g., repayment or default. Consistent with dynamic incentives, applicants are guaranteed a loan in the current period in the case of the former (repayment in previous period) while in the case of the latter (default in the previous period) they are barred from receiving a loan in the current period.
The non-private credit history refers to the non-repayment record of loan applicants in the previous period maintained by other microfinance institutions\textsuperscript{6}. Of course, this implies that these applicants have not received a loan from the given microfinance institution in the previous period. The (public) availability of non-private information is contingent upon voluntary information sharing on defaulters among competing microfinance institutions. But in equilibrium, information sharing on defaulters among competing microfinance institutions will only take place if the perceived benefits outweigh the associated costs of sharing information on defaulters.

Clearly, information sharing on defaulters among competing microfinance institutions has a positive effect on the profits of a given microfinance institution\textsuperscript{7}. For example, if loan applications include clients prone to default, possessing information on their identities at the time of loan appraisal will have a positive impact on repayment rates and hence the profits of a given microfinance institution. Likewise, as we shall show later, lack of information sharing on defaulters erodes the dynamic incentives associated with loan repayment, leading to a higher probability of strategic default by borrowers and hence lower profits. For the time being, in order to keep the model simple, we do not attempt to characterize the specific nature of these benefits. Therefore, the forthcoming analysis is independent of the specific nature of the benefits associated with information

\textsuperscript{6} Note that a client who repays a loan will not apply to other microfinance institutions since he is guaranteed a loan with the existing microfinance institution, whilst due to credit rationing applying for loans at other microfinance institutions does not guarantee a loan. Moreover, recall that microcredit contracts offered by all microfinance finance institutions are assumed to be identical.

\textsuperscript{7} Ideally, optimal information sharing between lenders involves sharing data on both “good” and “bad” clients. However, lenders are unlikely to share information on “good” borrowers with competitors due to the threat of the business stealing effect in competitive markets.
sharing on defaulters among competing microfinance institutions and remains valid as long as information sharing on defaulters is beneficial to a given microfinance institution.

3.2 A Simple Model of Sharing Private Information on Defaulters with Competing Microfinance Institutions

The problem of sharing private information regarding defaulters among competing microfinance institutions can be represented by an infinitely repeated stage game. Given $N$ identical microfinance institutions, let $\alpha_i$ denote the optimal lending volume of the $i^{th}$ microfinance institution and $z_i = \varphi(\alpha_i)$ denote the number of borrowers that default on their loans in a given period. We assume that a quadratic cost function $\left(\frac{z_i^2}{2}\right)$ represents the cost of sharing private information on last period’s defaulters with another microfinance institution, while $h(\sum_{j \neq i} z_j)$ represents the expected value of benefits accruing to a given microfinance institution from access to non-private information on defaulters in the previous period held by other microfinance institutions at the time of evaluating loan applications in the current period. By the law of diminishing returns, $h(.)$ is assumed to be a concave function to represent the (declining) positive effect on profits from possessing additional information on loan applicant’s repayment record. Using this notation, the expected payoff for the $i^{th}$ microfinance institution from sharing private information on $z_i$ defaulters with competing microfinance institutions in the stage game can be expressed as:

$$\pi_i = h(\sum_{j \neq i} z_j) - (N - 1)\left(\frac{z_i^2}{2}\right)$$
Note that the payoffs of microfinance institutions are interdependent. More specifically, the $i^{th}$ microfinance institutions decision to share private information about defaulters with its competitors benefits other competing microfinance institutions, whilst the burden of the cost of sharing private information on defaulters falls on the $i^{th}$ microfinance institution only and vice versa. Given this strategic interdependence, we look for a symmetric Nash equilibrium to the information sharing problem in order to derive the optimal decision rule vis-à-vis information sharing for a given microfinance institution. The similarities with a standard public good provision game are evident; however, a closer look will highlight some important differences. The optimization problem for the stage game is given by:

$$\pi^*_i = \max_{z_i} \left\{ h \left( \sum_{j \neq i} z_j \right) - (N - 1) \left( \frac{z_i^2}{2} \right) \right\}$$

Taking the F.O.C with respect to $z_i$ and imposing symmetry, it is straightforward to note that the optimal amount of private information sharing on defaulters ($z^*$) among competing microfinance institutions is uniquely given by $z^* = 0$.\(^8\) Intuitively, given that (private) information sharing is non-binding, the marginal benefit accruing to the $i^{th}$ microfinance institution from sharing information with other microfinance institutions is zero but with a non-zero marginal cost. Therefore, in equilibrium no information sharing

\(^8\)Because $\frac{\partial h(\sum_{j \neq i} z_j)}{\partial z_i} = 0$, the associated F.O.C is $z^*(N - 1) = 0$ and this obviously implies $z^* = 0$. 31
takes place because sharing (private) information on defaulters with competing microfinance institutions is not individually rational\textsuperscript{9}.

But is the lack of information sharing on defaulters Pareto optimal? Solving the analogous social planner problem:

\[
\pi^* = \max_z \left\{ Nh(z(N - 1)) - (N - 1)N \frac{z^2}{2} \right\}
\]

Taking the F.O.C, we get \(h'(z(N - 1)) = z\) and the F.O.C is sufficient because the second derivative: \(h''(z(N - 1)) - \frac{1}{N-1}\) is always negative. Note that since, \(h'(0)\) is positive and \(h'' < 0\) is a decreasing function by definition, while the RHS side of the F.O.C is the positively sloped 45\textdegree line through the origin. Therefore, by the single crossing property, we know that \(z^* > 0\) is the unique solution to the equivalent fixed point problem, i.e., \(h'(z(N - 1)) - z = 0\).

Clearly information sharing on defaulter is Pareto optimal. But in a non-cooperative equilibrium information sharing is non-binding, therefore the marginal benefit accruing to the \(i\)th microfinance institution is independent of the amount of information shared with competing microfinance institutions. As a result no information sharing on defaulters takes place in equilibrium. Intuitively, in the cooperative solution to the information sharing problem, the social planner equates the sum of marginal benefits to all the

\textsuperscript{9}As a simplification, throughout this paper we assume that competition is represented by \(N>2\), in reality this may not be so and information sharing may collapse only after \(N\) exceeds a certain threshold. The threshold level can be easily incorporated into the model at the expense of additional notation but without changing the major results.
microfinance institutions from information sharing (L.H.S of the F.O.C) with the aggregate (marginal) cost of sharing information (R.H.S of the F.O.C). While in a non-cooperative equilibrium, each microfinance institution selfishly equates private marginal benefit with private marginal cost of sharing information on defaulters. This is a classical manifestation of the free rider problem, whereby agents benefit from the private contributions of other agents but private contributions are individually costly. But interestingly, in contrast to the standard under provision result in public good game, we get no provision of non-private (or public) information on defaulters in equilibrium in the abovementioned settings.

Since this is an infinitely repeated game, other equilibrium strategies may exist which involve mechanisms to punish microfinance institutions that fail to disclose private information on defaulters to competitors. However, even in such a scenario, detection of non-compliance becomes difficult as the size and number of competing microfinance institutions increases over time. The cost of information sharing among lenders increases as the number of lenders in the market increase, limiting the efficacy of punishment strategies and resulting in a lack of information sharing in equilibrium. The simple model also explains the fact that despite the perceived benefits of credit bureaus maintaining records of defaulters, microfinance institutions are reluctant to contribute to their onetime setup costs\(^{10}\). Similarly, even when such credit bureaus are set up with the help of donor

\(^{10}\) By backwards induction, contributing towards the one time fixed cost of credit bureaus is not sub-game perfect. Because there will be no private information sharing on defaulters between microfinance institutions in subsequent periods, therefore contributions towards the fixed cost of setting up a credit bureau initially is simply not sequentially rational.
funds, they seldom remain functional beyond a certain period due to the lack of incentives to share private information on defaulters with competing microfinance institutions. In simple words, as long as the private costs of information sharing on defaulters exceed the associated private benefits, adjustment towards the optimal outcome cannot occur due to the free-rider problem.

However, the primary focus of this paper is to examine the supply side dynamics of microfinance sector in less developed countries. Nonetheless, in order to succeed in this endeavor, we need to fathom the implications of the abovementioned result on the demand side, i.e., borrower’s behavior. Therefore in the next subsection, we develop a simple strategic default model to examine how the behavior of borrowers is affected by the lack of information sharing on defaulters among competing microfinance institutions.

3.3 The Importance of Dynamic Incentives in the Microfinance Revolution

It is well known that a debt contract is enforced if the benefits from repayment exceed the costs associated with default. However, in the presence of several institutional voids in less developed countries, enforcement of microcredit contracts is not an easy task. Moreover, in the absence of physical collateral, the likelihood of strategic default increases significantly, leading to potentially high rates of default (Kelly et al. 2003) and at times even complete unraveling of microcredit markets. However, although group lending or joint liability contracts effectively transfer the costs of client selection (ex-ante adverse selection) and monitoring (ex-ante moral hazard) from microfinance institutions
to borrowers, they have a limited impact on the likelihood of strategic default (Kono & Takahashi 2010). Dynamic incentives or the threat of termination of credit, are widely believed to be the panacea to the problem of strategic default arising from poor debt contract enforcement in countries characterized by weak institutional environments (Hoff & Stiglitz 1990).

So what are dynamic incentives and how do they work? In essence, dynamic incentives use the threat of exclusion from future credit to incentivize the repayment of outstanding loans in the current period. In simple words, borrowers who repay their loan in the current period are guaranteed a loan in the next period, whilst borrowers who default in the current period are barred from future access to credit. Given the importance of microcredit to households excluded from the formal financial sector (project finance, consumption smoothing, and at times even disaster insurance), borrowers go to great lengths to repay outstanding loans in order to remain in good standing and thus maintain (guaranteed) access to future credit. Put simply, due to poor contract enforcement and the absence of collateral, dynamic incentives provided by the option value of future access to credit services (contingent on repayment) serve as a potent deterrent to default in microfinance. Consequently, dynamic incentives are viewed as a major factor behind the surprisingly high repayments rates observed in the microfinance industry around the world (Weiss & Montgomery 2005).
Given the results from the previous subsection, we now develop a stylized strategic default model to examine the effects of competition on dynamic incentives and hence the probability of strategic default, in the absence of information sharing on defaulters in a given microcredit market. The underlying model is similar to the canonical strategic default model described by Kono & Takahashi (2010) in their survey paper examining the commonly employed theoretical models in the microfinance literature. In many ways, our modeling approach is also related to Adjognon et al. (2015) who look at the effect of competition on default in input-credit markets, Tedeschi (2006) who endogenizes the default penalty associated with dynamic incentives and Gine et al. (2010) who examines the differential effect of dynamic incentives on borrower behavior in the presence of adverse selection. However, unlike previous work, we characterize the adverse impact of competition on the probability of strategic default whilst identifying mechanisms or channels (i.e., extensive and intensive measures of competition) that lead to the manifestation of this effect.

3.4 A Simple Model of Strategic Default with Dynamic Incentives

We assume that all borrowers are infinitely lived, risk neutral agents seeking to maximize the discounted stream of expected lifetime income. For sake of simplicity, let $V^*(r)$ denote the expected value of discounted lifetime income with access to credit and $W^*$ denote the expected value of discounted lifetime income without access to credit for a given representative borrower. Here, $r$ denotes the equilibrium interest rate in the given microcredit market and $V^*(r) \geq W^*$ by definition. Each borrower has access to a project
that requires an investment of 1 unit of capital each period, and generates a stochastic return of $\theta$ randomly distributed between $[\underline{\theta}, \bar{\theta}]$ with distribution function $F(\theta)$. It is well known that distribution function of a standard normal random variable is strictly increasing, i.e., $F'(\theta) > 0$ and $F''(\theta) > 0$ for project realizations below the mean of $\theta$ and $F''(\theta) < 0$ for values of $\theta$ above its mean. Borrowers do not have access to the formal financial sector or savings. Therefore, they cannot undertake the project without taking out a loan from a microfinance institution. We assume that in any given period, a borrower can only work on one project, hence takes out a single microloan\textsuperscript{11} and realizations of project return are assumed to be sufficient to cover loan repayment i.e. the lower bound of the support of the project return exceeds the amount the borrower is required to repay or he has other means to repay the loan even when faced with an adverse project realization. Lastly, in order to digress from issues related to ex-ante moral hazard, we assume that a borrower’s actions cannot influence the return generated from the project, i.e., there is no ex-ante choice over effort levels.

In the spirit of this paper, we assume that a given microcredit market is populated with $N$ identical microfinance institutions. Each microfinance institution offers a standard loan contract, i.e., $\$1$ loaned out at the start of the period with a repayment of $(1+r)$ due at the end of the period\textsuperscript{12}. To incorporate dynamic incentives into the model, borrowers of a

\textsuperscript{11} In case a loan application is approved by multiple microfinance institutions, the borrowers randomly selects a loan contract (recall all microloan contracts are identical in our setting). Of course, potential borrowers only submit a maximum of one application to a given microfinance institution at time $t$.

\textsuperscript{12} The number of MFIs in a given region ($N$) and the interest rate ($r$) are determined endogenously, we characterize the latter in the next section and assume the former is fixed in the short-run.
given microfinance institution are guaranteed another loan upon repayment of the previous outstanding loan, while defaulters of a previous loan are not granted another loan. The borrower either repays the loan in full or defaults in full, no partial repayments are allowed. In order to simplify the analysis and focus on the strategic default decision, we assume that borrowers can always repay the loan if he chooses to do so. The borrower will choose to repay if, and only if, the discounted, expected lifetime benefits of repayment exceed the discounted, expected lifetime costs of default. The borrowers discount future payoffs by a factor of $\delta$, per period, where $0 < \delta < 1$. In order to capture uncertainties and risks, such as social stigma and litigation, associated with strategic default, we assume that if a borrower decides to default, then with probability $q$, the microfinance institution successfully litigates against the borrower and in that case is entitled to seize the (entire) realized project return.\(^{13}\)

It is straightforward to show that dynamic incentives, i.e., guaranteed access to credit in future upon repayment of an existing loan, reduces the probability of strategic default. Let $p^*_1$ denote the probability of default in the absence of dynamic incentives. Obviously, rational agents will choose to default ex-post only if the expected benefits of default exceed the benefits of loan repayment in a given period: $(1 - q) \theta \geq \theta - (1 + r)$.\(^{14}\) This gives us the project return threshold for default: $\theta_{1} \leq \frac{1+r}{q}$ and hence the probability of

\(^{13}\)This is just an analytical simplification; identical results can be obtained with a concave period utility function but at the expense of additional algebra.

\(^{14}\)Note that the inequality represents the decision to default ex-post, i.e., after the realization of the actual project return. This is different from the ex-ante participation constraint discussed in section 5.1 which entails the decision to enter into a debt contract before the realization of actual project return. Obviously if the ex-ante participation constraint is non-binding then the question of ex-post default is immaterial.
strategic default, i.e., \( p_1 = F \left( \frac{1+r}{q} \right) \). Likewise, let \( p_2 \) denote the probability of strategic default with dynamic incentives. The agent will default (ex-post) in a given period only if the discounted value of expected benefits from default exceeds the discounted value of loan repayment, i.e.,

\[
(1 - q)\theta + \delta W^r \geq \theta - (1 + r) + \delta V^r(\theta).
\]

Simplifying we get the following project return threshold for strategic default:

\[
\hat{\theta}_2 \leq \frac{1+r+\delta(W^r-V^r(\theta))}{q}.
\]

Since, \( V^r(\theta) \geq W^* \) by assumption and the distribution function is strictly increasing \( F'(\theta) > 0 \) by definition, we get the following result:

\[
p_2 = F \left( \frac{1+r+\delta(W^r-V^r(\theta))}{q} \right) \leq p_1 = F \left( \frac{1+r}{q} \right),
\]

i.e., dynamic incentives reduce the probability of strategic default.

3.5 The Effect of Competition on the Likelihood of Strategic Default

Classical economic theory suggests that increased competition is synonymous with improvements in different measures of performance. However, it is well known that this conventional wisdom can fail in financial markets beset by information asymmetries and other strategic interdependencies (McIntosh & Wydick 2005 and Guha & Chowdhury 2013). For instance, the power of dynamic incentives relies upon an endogenously generated default penalty equal to the lost value of access to future credit (Beasley & Coate 1995). However, a higher default penalty translates into a lower probability of strategic default and vice versa. Therefore, the efficacy of dynamic incentives vis-à-vis repayment rates in a standard strategic default model is dependent upon the effective exclusion of defaulters from access to future credit. Likewise, under different settings Hoff & Stiglitz (1998) show that dynamic incentives are weakened by entry of new
lenders into the markets since this improves the reservation loan contract available to borrowers in case of default.

However, in a competitive market with multiple microfinance institutions, dynamic incentives can be sustained only if there is perfect information sharing on defaulters among competing microfinance institutions in order to exclude defaulters from access to future credit. In the absence of information sharing on defaulters among competing microfinance institutions, the penalty from the denial of future credit is significantly diluted because defaulters can apply for loans at competing microfinance institutions and secure future credit with non-zero probability. Consequently, compared to the standard dynamic incentive model described above, a defaulter is no longer (perfectly) excluded from future access to credit in this case. Clearly, this diminishes the penalty from default and leads to a higher aggregate probability of strategic default. Note that in the presence of a single microfinance institution in a given microcredit market, i.e., a monopoly, there is no non-private information on defaulters. Hence, in the case of default, defaulters can be easily identified and penalized by exclusion from access to future credit. Consequently, dynamic incentives of loan repayment remain intact in a monopolistic microcredit market, independent of information sharing mechanisms.

The existing literature on microfinance does not account for the effect of the abovementioned institutional features on dynamic incentives and hence default rates. Often, the simplifying assumption of a single provider of microcredit services is used to
overlook issues related to the impact of competition on dynamic incentives and hence default rates. We try to incorporate these issues into the strategic default model and illustrate that in the absence of information sharing on defaulters, both intensive and extensive measures of competition can adversely impact loan repayment rates.

3.6 Strategic Default in the Absence of Information Sharing on Defaulters between Competing Microfinance Institutions

Recall that excess demand of credit services vis-à-vis supply of credit is an important feature of the microfinance sector in less developed countries. More formally, if $k_i$ denotes the (endogenously determined) lending reserves of a representative microfinance institution in a given region and $L$ denotes the (given) aggregate demand for microcredit loans in the region, then $\sum_{i=1}^{N} k_i = K < L$. Therefore, all else equal, the probability of the success of a microloan application submitted to the $i^{th}$ microfinance institution is an increasing function of the size of the lending reserves of the $i^{th}$ microfinance institution relative to aggregate loan demand, i.e., $\frac{k_i}{L}$ due to credit rationing.$^{16}$

For example, in the absence of information sharing on defaulters among microfinance institutions, a clean borrower (one who has never defaulted) can default on a loan taken from the $i^{th}$ microfinance institution and still manage to get a loan next period with non-

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$^{15}$ This equals the quantity of loans demanded since loan size is normalized to $1. Of course, $K$ and $L$ are functions of other variables including the lending rate $r$, cost of lending $c$ and the risk-free rate $\bar{r}$. We suppress this dependence for expositionary clarity here.

$^{16}$ More realistically, the number of clients who repaid loans in the previous periods needs to be subtracted from both the numerator and denominator. Nevertheless, the basic idea remains the same.
zero probability by approaching the remaining $N - 1$ microfinance institutions in the region. Therefore, in general, the probability that a $l^{th}$ time defaulter gets a loan next period, i.e., $\mu_l$, can be expressed as a function of the ratio of lending reserves of the remaining microfinance institutions relative to the given aggregate loan demand, i.e., $\sum_{l=1}^{N-1} \frac{K_l}{L}$, where the sub-index $l$ ($1 \leq l \leq N$) captures the number of times a given defaulter has defaulted on the loans from different microfinance institutions. Note that since all microfinance institutions are identical by assumption, $\sum_{l=1}^{N-1} \frac{K_l}{L}$ can be rewritten as $\frac{(N-l)K_l}{L} = \frac{(1-l)K}{L}$. Finally, the probability that a $l^{th}$ time defaulter gets another loan can be expressed as $\mu_l = y\left(\frac{(N-l)K_l}{L}\right)$ where $y(0) = 0$, $y\left(\frac{K}{L}\right) < 1$, $y' > 0$ and hence $\frac{\partial \mu_l}{l} < 0$. For sake of simplicity, we assume $y(\cdot)$ is a linear function\(^{17}\).

Note that due to credit rationing a given borrower defaults “strategically” only if the project return is below a certain threshold $\tilde{\theta}$, hence the expected time before an agent defaults is given by: $\frac{1}{F(\tilde{\theta})} > T^* > 1$. Although unlikely, it is theoretically possible that over time a given borrower defaults on loans received from all the $N$ microfinance institutions present in the region. As a result he is no longer able to take out further loans and consequently (permanently) drops out of the pool of loan applicants\(^{18}\). However, given $T^*$ is large enough and with several competing microfinance institutions, it is

\(^{17}\)The utility of this assumption will become obvious in section 4.2, when we try to sign the second derivative of the aggregate default function.

\(^{18}\)This eventuality nontrivially impacts the assumption of fixed aggregate demand ($L$) at any given period, complicating the derivation of the probability of strategic default.
reasonable to assume that a given defaulter never “runs out” of potential microfinance willing to consider his loan application. Another way to rule out this unlikely and uninteresting case is to assume that after a certain number of periods say $T_1$ the default records of previous defaulters are thrown away by microfinance institutions given cost considerations of tracking dormant past clients. Therefore, as long as $(N - 1)T^* < T_1 < NT^*$, all borrowers, regardless of default history, have a chance to secure credit at any given time in expectation. Moreover, note that $\mu_t$ approaches 0 as $t$ becomes large. Therefore, a defaulter is less likely to default as $t$ increases because of the lower probability of securing another loan in future and the hence a higher default penalty.

In summary, if a borrower chooses to repay the outstanding loan from the previous period he is guaranteed access to credit in the current period and thus is able to avoid the uncertainty associated with the rejection of new loan applications due to credit rationing. However, a defaulter is no longer able to apply for a loan with microfinance institutions on whose loans he has defaulted on in the previous periods. Although he can apply for a new loan with other microfinance institutions in the next period, in the presence of credit rationing, the probability of obtaining another loan is obviously less than one. Intuitively, in the absence of information sharing on defaulters, the dynamic repayment incentives created by denial to access to future credit are diminished. Consequently, the penalty of default is reduced, leading to higher aggregate probability of default. Mathematically, a borrower will choose to default (ex-post) in this period if the discounted value of
expected benefits from default exceeds the discounted value of expected benefits from repayment, i.e.:

$$\delta \mu_t V^*(r) + (1 - \mu_t)\delta W^* + (1 - q)\theta \geq \theta - (1 + r) + \delta V^*(r)$$

This implies that the project return threshold for defaulting strategically is given by:

$$\hat{\theta}_3 \leq \frac{1 + r + \delta (1 - \mu_t)(W^* - V^*(r))}{q}$$

Thus, the associated aggregate default probability $p_3$ is given by

$$F\left(\frac{1+r+\delta (1-\mu_t)(W^*-V^*(r))}{q}\right),$$

which is strictly greater then $p_2 = F\left(\frac{1+r+\delta (W^*-V^*(r))}{q}\right)$ because $F' > 0$, while $V^*(r) \geq W^*$ and $0 \leq \mu_t \leq 1$.

In a nutshell, lack of information sharing about defaulters among microfinance institutions diminishes the dynamic incentives of repayment or the default penalty (i.e., lost option value of expected benefits from future access to credit) in case of strategic default, leading to higher default rates. It is straightforward to verify that if $\mu_t = 0$ (defaulter never gets another loan due to lack of competing microfinance institutions or perfect information sharing among competing microfinance institutions), then $p_3 = p_2$, i.e., full restoration of dynamic repayment incentives. While, if $\mu_t = 1$ (defaulter always gets another loan due to excessive competition or no credit rationing), then $p_3 = p_1$, i.e., full abolition of dynamic repayment incentives. The strategic default probabilities under different scenarios described above are summarized in figure 1 below:
This stylized model allows us to arrive at some interesting conclusions, necessary to derive the forthcoming results about the effect of competition and resource allocation on default rates in microfinance. The threshold project return at which the borrower is indifferent between repayment and default be given by

\[ \hat{\theta}_3 = \frac{1+r+\delta(1-\mu_i)(W^*-V^*(r))}{q} \]

Given the distribution function \( F(\cdot) \), we can define probability of default as \( F(\hat{\theta}_3) \) and use the chain rule to compute the effect of extensive competition (increase in number of microfinance institutions whilst keeping the total size of resources devoted to microfinance fixed) on default rates all else equal:

Proposition1A: \[
\frac{\partial p_3}{\partial N} = \frac{\partial F(\hat{\theta}_3)}{\partial \hat{\theta}_3} \frac{\partial \hat{\theta}_3}{\partial \mu_i} \frac{\partial \mu_i}{\partial N} = F'(\hat{\theta}_3) \frac{\delta(V^*(r)-W^*)}{q} \frac{y(1-R)^{K/\theta}}{L} \leq 0 \text{ for } \forall l \in [1-N]
\]

The inequality above holds because \( F'(\cdot) \) and \( y'(\cdot) \) are increasing functions by definition and clearly \( V^*(r) > W^* \). Intuitively, as the number of microfinance institutions increase
for a given level of aggregate lending reserves, the share of each microfinance institution as the percentage of aggregate lending reserves decreases. Consequently, the expected penalty of a onetime default \((l = 1)\) by a borrower of a given microfinance institution is diminished because each microfinance institution represents only a small share of the overall market. Hence, the decision to default has a smaller impact on the probability of obtaining another loan in future. Anecdotal evidence, highlighted earlier, lends support to this result. For example, increasing default rates in the microfinance hubs of countries like Bangladesh, India, Pakistan and Uganda over the past decade have coincided with an influx of new entrants into microcredit markets in these regions.

Similarly, all else equal, we can employ the chain rule to look at the effect of intensive competition (increase in the level of resources devoted to microfinance sector whilst keeping the number of competing microfinance institutions constant) on default rates:

\[
\text{Proposition 1B}: \frac{\partial p_3}{\partial K} = \frac{\partial F(\hat{\theta}_3)}{\partial \hat{\theta}_3} \frac{\partial \hat{\theta}_3}{\partial \mu_l} = F' \left( \hat{\theta}_3 \right) \frac{\delta (V^*(r) - W^*)}{q} \frac{\left(1 - \frac{1-l}{N} \right) K}{N L} \geq 0 \text{ for } \forall l \in [1 - N]
\]

The inequality holds because \(l \leq N\) in addition to the results used previously for the derivation of Proposition 1A. The comparative static result shows that as the resources devoted to microfinance sector increase, the probability of default increases. The logic is straightforward, additional resources reduce the gap between excess demand of microcredit loans and the limited supply of loanable funds, leading to a decline in credit
rationing. In other words, an increase in the loan supply increases the ex-post probability of getting a new loan for all potential borrowers including defaulters. However, lower credit rationing practices dilute dynamic incentives associated with loan repayment by reducing the penalty of default, i.e., larger size of loanable funds increase the chances of a borrower getting a loan from another microfinance institution after defaulting on his existing loan obligation. Interestingly, note that in the absence of competition (i.e., $N = 1$), additional resources pumped into the sector do not result in an increase in default rates because in that case $\mu_1 = y\left(\frac{(1-\frac{\lambda}{L})K}{0}\right) = y(0) = 0.19$

This result also fits the stylized facts associated with the development of microfinance sector in less developed countries. For instance, initially with only a few key players, additional resources devoted to microfinance sector did not result in an increase in default rates. However, higher levels of funding in the face of increasing levels of competition in the absence of information sharing on defaulters eroded borrower discipline in several microfinance markets and resulting in a sharp spike in default rates. For example, it is widely believed that an exponential rise in funding to microfinance institutions in India encouraged opportunistic behavior among borrowers, which eventually transpired into the infamous microfinance crisis of 2010. Similar crises have been documented in the microfinance sector in Nicaragua, Bosnia and Uganda, to name a few.

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$^{19}$Clearly, in this case, the number of microfinance institutions with which a client can default ($l$) cannot exceed 1.
3.7 Overview of Results

To summarize, we first established that no information sharing on defaulters among microfinance institutions is the unique Nash equilibrium of the infinitely repeated stage game described in Section 4.1, although sharing information on defaulters is Pareto optimal. Thereafter, we developed a stylized strategic default model to show that dynamic repayment incentives are adversely affected by increasing levels of competition in the absence of information sharing on defaulters. In particular, all else equal, the probability of default unambiguously increases with both intensive (higher number of competing microfinance institutions holding aggregate resources devoted to microfinance constant) and extensive (higher levels of resources devoted to microfinance institutions holding number of competing microfinance institutions constant) measures of competition. More formally, the analysis highlights that in the abovementioned institutional settings (credit rationing, lack of information sharing on defaulters among lenders etc.) the aggregate probability of default is a function of different measures of competition. Although the adverse impact of competition on financial markets is well known (Hoff & Stiglitz 1998, McIntosh & Wydick 2005 and Guha & Chowdhury 2013), the present work identifies mechanisms relevant to the performance of the microfinance industry that have not been fully examined in the literature.

The empirical literature lends support to the results derived from the abovementioned stylized strategic default model. For example, based on a large dataset, Assefa et al. (2013), find that increasing levels of competition between 1995-2008 was negatively
associated with repayment performance. Likewise, McIntosh et al. (2005) document the adverse impact of increases in competition on repayment rates in Uganda. In general, anecdotal evidence from the microfinance sector in less developed countries like Bangladesh, India, Pakistan, Uganda and Kenya, also conforms to the predictions made by our model. These findings highlight the fact that the institutional environment has an important effect on aggregate default rates. Moreover, often the success of microcredit in the past has been driven by the context or institutional environment of a given region. For example, monopolistic microcredit markets and limited loan reserves relative to loan demand during the early period of the microfinance revolution resulted in high dynamic incentives for loan repayment and hence low default rates. The low default rates attracted the interest of donors and entrepreneurs towards the microfinance sector. However, in the absence of an appropriate institutional environment in less developed countries, increasing levels of competition along with higher resources devoted to the microfinance sector, a standard policy prescription for successful poverty alleviation strategies, unfortunately led to higher default rates and often eventual failure.

4 Effect of Intra-Firm Competition on Default Rates under Different Market Structures

The previous Section highlighted that increases in different measures of competition can potentially lead to deterioration in repayment rates in the absence of information sharing on defaulters among microfinance institutions. However, defaults in equilibrium are a rule rather than an exception in the microfinance sector. The fundamental questions about
default rates in microcredit markets are not related to its existence in equilibrium but rather to its extent. Or in other words, we want to answer the question: how much is too much? From a policy perspective, we are primarily interested in characterizing the adverse effects of intra-firm competition on aggregate default rates under different market structures and benchmarking it against the solution to the analogous social planner problems.

To this end, we first determine the equilibrium lending rate in microcredit markets characterized by the aforementioned institutional features. Given the equilibrium lending rate, we determine the optimal lending volumes and hence the equilibrium default rates under different market structures e.g. non-credit constrained profit maximizing microfinance institutions, credit constrained profit maximizing microfinance institutions and outreach maximizing altruistic microfinance institutions. Thereafter, the equilibrium default rates are compared to the corresponding default rates derived from the solution to the analogous social planner problems in order to determine whether intra-firm competition leads to “inefficiently” high default rates and compare and contrast the “size” of the negative competition externality under different market structures.

4.1 Equilibrium Interest Rates with Ex-Ante Adverse Selection & Strategic Default

As described in Section 2, microcredit markets in less developed countries are characterized by credit rationing due to the excess demand of credit vis-à-vis supply, a competitive landscape with several rational lenders, usually a standard loan offering
(pooling loan contracts), information asymmetries caused by ex-ante adverse selection and a weak institutional environment (i.e., poor contract enforcement). Obviously the presence of these factors leads to considerable complications in the analysis of microcredit markets in less developed countries. However, even in the absence of many of these factors, financial transactions are inherently different from real or commodity/service based transactions. Unlike real transactions, financial transactions involve an exchange of a certain purchasing power in the current period (e.g. $100 or a car etc.) against a “promise” to repay in future. Evidently, all promises to repay are not equal and the “quality” of a promise varies from one borrower to another. Therefore, in essence, financial transactions involve an exchange of an exact value in the present with an uncertain value in future. Accordingly, lenders face the difficult task of valuing an uncertain promise to repay.

Moreover, in practice, due to stochastic project return and limited liability, lenders are exposed to the downside risk of adverse project realizations but do not benefit from favorable project realizations, while an inability to observe the “true” type of borrowers leads to pooling within classes of borrowers. In the presence of these factors, the so called “law” of demand and supply does not always hold in financial markets. Whereby, prices are expected to adjust until demand equals supply. In fact in financial markets, equilibrium is not synonymous with market clearing but is defined as an allocation where market participants have no incentive or opportunity to deviate from the equilibrium
outcome. This understanding fundamentally changes the underlying solutions concepts needed to examine equilibrium in financial markets.

Stiglitz & Weiss (1981) were among the first to expound some of these concepts in their research on credit rationing in financial markets. Their seminal contribution was that in the presence of ex-ante adverse selection (or moral hazard), the interest rate on a loan serves as a screening device. Therefore, lenders choose not to increase the quoted interest rates even when there is excess demand for credit due to the adverse selection (or ex-ante moral hazard) effects of a higher interest rate. Higher quoted interest rates attract riskier borrowers (ex-ante adverse selection) or riskier actions (ex-ante moral hazard) whilst driving out safe borrowers from the applicant pool, resulting in lower repayment rates and hence lower profits. Consequently, in contrast to standard textbook economics, the price of loans (interest rate) does not adjust such that there is zero excess demand for credit. The result is credit rationing in equilibrium, i.e., some applicants are granted loans whilst other observationally identical applicants are rejected even though they are willing to pay the market interest rate or at times even more. In summary, Stiglitz & Weiss proved that the benefits of an increase in interest rates (the price effect, i.e., higher profits due to higher prices) are counteracted by the associated costs of higher defaults rates (the screening effect, i.e., lower profits due to higher default rates). Thus, equilibrium interest

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20The quoted loan rate determines the amount that borrowers “promise” to repay and the expected rate of return on a loan is the quoted rate adjusted for expected loss in case of default.
rates are determined by the tradeoffs between the price and screening effects, independent of the standard market clearing arguments.

More formally, in the Stiglitz & Weiss (1981) model, each borrower gets the same loan size and the proceeds are invested in the project with a stochastic return. The market is populated with a continuum of borrower types, possessing project with identical expected return but different project return variances. The safe or good types have a lower project return variance compared to the risky or bad types, leading to lower defaults by the good types on average. On supply side, the market is competitive with several profit maximizing firms. Each firm knows the proportion of good and bad borrowers in the population but cannot tell the difference between loan applicants from each type. The cost of loanable funds to the lenders is assumed to be exogenously fixed.

Under these settings, Stiglitz & Weiss (1981) rigorously prove that as the quoted interest rate is increased, good borrowers begin to drop out of the potential client pool at a faster rate compared to the bad borrowers due to the adverse selection effect, leading to a decline in profits after interest rates cross a certain threshold. In a nutshell, the bank is caught in a dilemma whereby it cannot get rid of the bad borrowers without losing the good borrowers, since the good borrowers are more sensitive to increase in interest rates. The upshot of their work is succinctly summarized in the figure below. Figure 2 shows that expected profit is maximized at a given interest rate in the presence of credit rationing independent of the standard supply/demand models that entail interactions.
between loan supply and credit demand until markets clear, i.e., non-zero excess demand for credit in equilibrium persists.

Figure 2 Interest Rates: The Price of a Loan and a Screening Device

The Stiglitz & Weiss (1981) paper is based on a static model where there is no voluntary default, i.e., strategic default and borrowers always repay if they have the ability to do so, i.e., when project proceeds can cover the cost of loan plus interest. Nevertheless, the basic idea that ex-ante adverse selection negatively impacts ex-ante default rates can be extended to study the impact of ex-ante adverse selection on the probability of ex-post default rates (strategic default). Therefore, we exploit their basic idea to show that profit maximizing interest rate in the latter case is also determined by information effects as opposed to the standard demand/supply arguments.
On the demand side, for simplicity we assume only two types of borrowers\textsuperscript{21}. Like Stiglitz & Weiss (1981), mean preserving spreads are used such that the expected return of the projects of both the good and the bad type of borrowers is equal but with unequal variances.

\textbf{Figure 3 Project Return Distributions of Good and Bad Types}

The probability density functions along with the corresponding distribution functions for project return are depicted in upper and lower panels of figure 3, respectively. Note that the distribution function of the bad types (red) is always above the distribution function of good types (blue), illustrating that the probability of falling below any given project

\textsuperscript{21}The analysis can be extended for a continuum of borrowers but at the expense of dealing with considerably complicated mathematics.
return is higher for the bad types compared to good types. This implies that, all else equal, bad types are more likely to default.

Lenders offer a uniform (pooling) loan contract with a quoted interest rate of \( r \) and cannot differentiate among the types of borrowers but know the fraction of each in the applicant pool. We assume that both good and bad types have identical endowments of \( \omega \) in each period but different rates of return on an outside investment option, i.e., \( \rho^1 \) and \( \rho^2 \) respectively, where \( \rho^1 > \rho^2 \). Thus, the associated ex-ante loan contract participation constraints for each type are given by:

\[
E(\theta^1) - (1 + r) \geq \rho^1 \omega \\
E(\theta^2) - (1 + r) \geq \rho^2 \omega
\]

Since, \( E(\theta^1) = E(\theta^2) = E(\theta) \), it is easy to see that the participation constraint of the good types bind at a lower interest rate \( (E(\theta) - \rho^1 \omega - 1) \) compared to the bad types \( (E(\theta) - \rho^2 \omega - 1) \). Therefore, the good types drop out of the applicant pool once the interest rate surpasses this threshold, leaving only the bad types in the applicant pool. But what happens to the aggregate probability of ex-post (strategic) default once the good types drop out? The answer is not as simple as it seems.

Introducing an index for types, recall that probability of ex-post default in the absence of information sharing on defaulters among microfinance institutions was derived in Section 3.6 as:
By our assumptions we know that $V^*(r) = \frac{E(\theta^1- (1+r))}{1-\delta} = \frac{E(\theta^2- (1+r))}{1-\delta} = \frac{E(\theta)-(1+r)}{1-\delta}$, but at the same time $W^{*1} > W^{*2}$ because $\frac{\rho^2 \omega}{1-\delta} > \frac{\rho^2 \omega}{1-\delta}$. And all else equal the probability, of strategic default increases with value of outside option, i.e., $\frac{\partial F(\hat{\theta}^i)}{\partial W^{*i}} > 0$. Intuitively, the size of the default, i.e., denial of future access to credit is diminished if the income in the autarky state (i.e., outside option) is higher.

However, in order to reconcile the contradicting effects of borrower type on the probability of ex-post default, we assume that the mean preserving spreads are sufficiently large while the differences in the return on the outside option are adequately small such that:

$$F^1(\hat{\theta}^1) < F^2(\hat{\theta}^2) \quad \text{although} \quad \hat{\theta}^1 = \frac{1+r + \delta(1-\mu)(W^{*1} - V^*(r))}{q} > \hat{\theta}^2 = \frac{1+r + \delta(1-\mu)(W^{*2} - V^*(r))}{q}.$$  

We feel this is also a more reasonable conclusion because in practice one would expect good types to default (ex-post) less frequently compared to bad types. However, the analysis also highlights that simple results derived from a static model are no longer straightforward after addition of simple dynamics. The graphical representation of abovementioned arguments in figure 4 crystallizes the desired conclusion.
Given that the good types are less likely to default strategically, i.e., $F^1(\tilde{\theta}^1) < F^2(\tilde{\theta}^2)$. It is easy to see that the profit maximizing $r^*$ is set sufficiently low such that the ex-ante participation constraint of the good types is satisfied: $E(\theta^1) - (1 + r^*) > \rho^1 \omega + \epsilon$, where $\epsilon$ is small in order to ensure that $V^*(r^*) - W^{*1} > 0^{22}$. Of course, this implies that the ex-ante participation constraint of bad types is satisfied and dynamic repayment incentives for bad types ($V^*(r^*) - W^{*2} > 0$) are also intact. If interest rates are increased beyond $r^*$ then the good types drop out leading to a higher (overall) probability of strategic default and hence lower profits (the screening effect). On the other hand, profits can be increased if interest rates are below $r^*$ by increasing the interest rate (the price effect). Therefore, akin to Stiglitz & Weiss (1981), in the presence of ex-ante adverse

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22 If the participation constraint for the good types strictly binds, i.e., $E(\theta^1) - (1 + r) = \rho^1 \omega$ than this implies that $V^*(r) = W^{*1}$. Hence, there are no dynamic repayment incentives for the good types leading to an increase in the probability of strategic default among the good types and hence lower overall profits for lenders.
selection and ex-post default, $\hat{\tau} = E(\theta) - (1 + \rho^1 \omega)$ serves as an interest rate ceiling derived from profit maximizing behavior of lenders independently of standard market clearing conditions.

Anecdotal evidence from the microfinance sector lends support to the abovementioned conclusions. Quoted interest rates on microloans have remained more or less identical over time despite significant changes in the supply of loanable funds. For example, an increasing loan supply, spurred by favorable donor funding, has not always lead to a reduction in interest rates as would be implied by a standard demand-supply model. Moreover at times, even rising lending costs have not resulted in any meaningful increase in quoted interest rates in some areas. This observation also suggests that interest rates are primarily driven by information effects (moral hazard and adverse selection) as opposed to supply-demand considerations. Although, after a certain threshold when supply of loanable funds is physically much greater than the demand for credit, it is likely that standard supply and demand arguments hold whereby interest rates fall drastically as lenders try to “steal” competitor’s business. However, given the extent of poverty in South Asia and Africa this seems very unlikely in the near future.

The abovementioned analysis is primarily based on the work of Stiglitz & Weiss (1981) and the results are no longer applicable if separating loan contracts are considered. Casini (2015) and Navajas et al. (2003) look at default rates under separating loan contracts, a setting which is perhaps more appropriate for developed microcredit markets in South
America. In summary, given uniform loan contracts, asymmetric information leads to credit rationing in equilibrium in which profit maximizing microfinance institutions charge a unique interest rate \( r^* \) independent of lending levels in equilibrium. Because raising interest rates above \( r^* \) leads to lower profits due to the negative effects of adverse selection, lowering the interest rate below \( r^* \) results in lower profits since lending volumes are capped by (endogenous) capacity constraints, i.e., reserves. In the next subsection we derive the equilibrium lending volumes to pin down the lending reserves and hence the equilibrium default rates under different market structures.

4.2 Negative Externality of Intra-Firm Competition among Credit-Unconstrained Lenders

Up until now we have treated lending reserves in microcredit markets as exogenous. However, in reality, the level of loan reserves is endogenously determined by the solution to the maximization problem of the representative microfinance institution in a given microcredit market. In this subsection, we develop a simple model to capture the underlying constrained optimization problem faced by microfinance institutions, allowing us to compare the equilibrium lending reserves and default rates under different market structures with the associated social optima, the primary objective of this paper.

Recall that, by Proposition 1B, in the absence of information sharing among competing microfinance institutions on defaulters, default rates are an increasing function of aggregate lending reserves. Evidently, the level of loan reserves is a function of optimal lending volumes. Therefore, armed with the equilibrium interest rate, we formulate an
infinite horizon, dynamic optimization problem to capture the objective function of a 
credit unconstrained profit maximizing microfinance institution and derive the optimal 
lending volumes and hence loan reserves.

For the time being, we focus on short run dynamics, holding the number of microfinance 
institutions in a given market to be exogenously fixed like Guha & Chowdhry (2013). 
We assume that \( N \) profit maximizing microfinance institutions operate in a given 
 microcredit market, each with the objective of maximizing its discounted stream of 
expected profits over an infinite horizon. Each microfinance institution has an initial loan 
reserve (equity) of \( e \) and can save/borrow from the central bank at a net rate of \( \bar{r} \) up to an 
upper limit of \( \bar{k} \). Thus, the maximum lending volume is capped by \( e + \bar{k} \). Each period, 
competing microfinance institutions simultaneously decide the interest rate to charge on a 
loan (\( r_i \)) and how much to lend, i.e., lending volume. The loan size is normalized to one 
unit so that the number of loans lent out also equals the monetary value of the loan 
portfolio. Let \( \alpha_i \) denote the number of loans made by the \( i \)th microfinance institution 
and \( c \) the origination cost for each loan, which is incurred at the beginning of each period. 
Finally, \( \bar{r} \) is the risk-free (net) rate of return on saving/borrowing with the central bank 
and microfinance institutions discount future payoffs at the rate of \( \beta \).

In the previous subsection we showed that in the presence of ex-ante adverse selection 
and ex-post moral hazard (strategic default) \( r_i = r^* \forall i \), where, \( r^* \) is the unique profit 
maximizing quoted gross lending rate in a given microcredit market. While, \( f(\sum_{j=1}^{N} k_i) \)
is the (aggregate) probability distribution function of strategic default in a given microcredit market and $f'\left(\sum_{j=1}^{N} k_i\right) > 0$ by Proposition 1B\textsuperscript{23}. Given a non-zero opportunity cost of capital, it is easy to see that, in equilibrium, the optimal lending reserves of a representative microfinance institution are given by $k_i = (c + 1)\alpha_i$, where $0 \leq (c + 1)\alpha_i \leq e + \bar{k}$. Given this setup, the objective function of a representative microfinance institution can be expressed as:

$$\max_{\{a^t_i\}_{t=1}^{\infty}} \sum_{t=1}^{\infty} \beta^t \left[ r^* \left( 1 - f\left( \sum_{j=1}^{N} (c + 1)\alpha_j^t \right) \right) \alpha_i^t - c\alpha_i^t - \alpha_i^t - \left( (c + 1)\alpha_i^t - e \right) \bar{r} \right]$$

s.t

$$0 \leq \alpha_i + c\alpha_i \leq e + \bar{k} \rightarrow 0 \leq \alpha_i \leq \frac{e + \bar{k}}{1 + c}$$

The first bracketed term in the period payoff function adjusts the profit maximizing gross quoted rate for defaults, i.e., $r^* \left( 1 - f\left( \sum_{j=1}^{N} (c + 1)\alpha_j \right) \right)$ represents expected repayment rate. Therefore, $r^* \left( 1 - f\left( \sum_{j=1}^{N} (c + 1)\alpha_j^t \right) \right) \alpha_i^t$ is the expected revenue or total cash inflow from lending activities. The lending costs or negative outflows associated with the loan principal and the marginal costs of loan origination are denoted by $c\alpha_i - \alpha_i$. In order to capture the opportunity cost of making additional loans, the last term in the period payoff captures the lender’s borrowing costs, i.e., if $(c + 1)\alpha_j > e$ or additional income from savings at the state bank if $(c + 1)\alpha_j < e$. Lastly, the period resource constraint

---

\textsuperscript{23} The aggregate probability distribution function of default in the market is the weighted sum of the probability distribution function of strategic default of the good and bad types, i.e., $F^1(\hat{\theta}^1)$ and $F^2(\hat{\theta}^2)$. Since both $F^1(\hat{\theta}^1)$ and $F^2(\hat{\theta}^2)$ are increasing in $\sum_{j=1}^{N} k_i$, their sum is also increasing in $\sum_{j=1}^{N} k_i$. 

62
ensures that outlays associated with loan principal and loan origination remain within the upper bound on lending resources, i.e., \(E + \bar{k}\) and are non-negative.

On closer analysis the solution to the cumbersome looking infinite horizon, constrained optimization problem is essentially equivalent to the solution of the following simpler unconstrained, period by period profit-maximization problem:

\[
\text{Max}_{0 \leq \alpha_i \leq \frac{E + \bar{k}}{1 + c}} \left( r^* \left( 1 - f \left( \sum_{j=1}^{N} (c + 1)\alpha_j \right) \right) \alpha_i - c\alpha_i - \alpha_i - \left( (c + 1)\alpha_i - e \right) \bar{r} \right)
\]

Note that although each firm maximizes profits with respect to the variable under its control, i.e., \(\alpha_i\), profits depend on the lending levels of competing firms as well because default rates are a function of aggregate lending reserves, i.e., \(f \left( \sum_{j=1}^{N} (c + 1)\alpha_j \right)\). Hence, from the perspective of a manager in a competitive market with the absence of information sharing on defaulters, the expected repayment rate is a function of a (known) lending volume of the given microfinance institution and an unknown quantity lent out by other lenders in equilibrium. This strategic interaction determines the aggregate lending volume and hence equilibrium default rates in microcredit markets.

Given strategically interdependent payoff functions and lack of coordination among competing microfinance institutions, we look for a (non-cooperative) symmetric Nash equilibrium of the abovementioned game. Taking the first order conditions (F.O.C) with respect to \(\{\alpha_i\}\) we get:
\[ r^* \left( 1 - f \left( \sum_{j=1}^{N} (c + 1)\alpha_j \right) \right) - (c + 1)f' \left( \sum_{j=1}^{N} (c + 1)\alpha_j \right) r^* \alpha_i - (c + 1)(1 + \bar{r}) \begin{cases} < 0 \text{ if } \alpha_i = 0 \\ = 0 \text{ if } \alpha_i \leq \frac{e + k}{1 + c} \\ > 0 \text{ if } \alpha_i > \frac{e + k}{1 + c} \end{cases} \]

Note that second derivative is given by \(-r^*[2f'\left(\sum_{j=1}^{N} \alpha_j\right) + (c + 1)f''\left(\sum_{j=1}^{N} \alpha_j\right)\alpha_i]\) and is strictly negative if \(f(.)\) is weakly convex, i.e., \(f''(.) \geq 0\), because \(r^*\) and \(c\) are positive by definition and \(f'\left(\sum_{j=1}^{N} \alpha_j\right) > 0\) by Proposition 1B. Consequently, the first order condition also becomes a sufficient condition for the optimization problem. We ignore the uninteresting corner solutions of no lending and lending at capacity but instead choose to focus on an interior solution of the problem. Summing over F.O.Cs for the \(N\) microfinance institutions we have:

\[ Nr^* \left( 1 - f \left( \sum_{j=1}^{N} (c + 1)\alpha_j \right) \right) - r^*f' \left( \sum_{j=1}^{N} (c + 1)\alpha_j \right) \left( \sum_{j=1}^{N} \alpha_j \right) (c + 1) - N(c + 1)(1 + \bar{r}) = 0 \]

In a symmetric Nash equilibrium \(\alpha_1 = \cdots \alpha_{i-1} = \alpha_i = \alpha_{i+1} = \cdots \alpha_N = \alpha^*\), where \(\alpha^*\) is the profit maximizing lending volume, substituting into the F.O.C we get:

\[ Nr^* \left( 1 - f \left( (c + 1)(N\alpha^*) \right) \right) - N\alpha^*r^*f' \left( (c + 1)(N\alpha^*) \right) (c + 1) - N(c + 1)(1 + \bar{r}) = 0 \]

---

24 Intuitively, the weak convexity of \(f(.)\) can also be derived from model primers given the threshold of strategic default (\(\bar{r}\)) is less than the mean of the stochastic project return (\(E(\theta)\)). If this is the case, it is well known that the distribution function of a standard normally distributed random variable is increasing and convex below the mean and increasing and concave above it, i.e., the mean of the random variable is a point of inflexion. Using the earlier assumption that the probability that a defaulter gets a loan is linear (\(y'(.) = 0\)) and taking the second derivative of the result shown in proposition 1B with respect to \(K\), we get:

\[ F' \left( \hat{\theta} \right) \frac{\delta(W' - W)}{q} \left( \frac{1 - K}{K} \right)^2 R \geq 0 \]. Alternatively, if \(f(.)\) is not weakly convex than \(2f' \left( \sum_{j=1}^{N} \alpha_j \right) \geq \left( c + 1 \right)f' \left( \sum_{j=1}^{N} \alpha_j \right) \) also guarantees the sufficiency of the first order condition.

64
Now let \( N\alpha^* = \bar{\alpha} \) denote the aggregate lending volume in this market structure scenario, substituting into the F.O.C and dividing throughout by \( N \) we get **Equation 1:**

\[
  r^*\left(1 - f\left((c + 1)\bar{\alpha}\right)\right) - \frac{\bar{\alpha}r^*}{N} f'\left((c + 1)\bar{\alpha}\right)(c + 1) - (c + 1)(1 + \bar{r}) = 0
\]

Equation 1, a nonlinear equation, implicitly determines the optimal lending volume and hence the default rates in a symmetric Nash equilibrium given a profit maximizing (gross) lending rate of \( r^* \). Multiplying and rearranging, we get the following root finding problem with \( \alpha \) as the free variable:

\[
\left[r^* - (c + 1)(1 + \bar{r})\right] - \left[\frac{\bar{\alpha}}{N} f'\left((c + 1)\bar{\alpha}\right)(c + 1) + f\left((c + 1)\bar{\alpha}\right)\right] = 0
\]

Positive lending volumes are guaranteed if and only if \( r^* > (c + 1)(\bar{r} + 1) \), which also implies that the first term in the square brackets is a positive constant independent of lending volumes. Note that the second term in the square brackets is a positively valued function of \( \bar{\alpha} \) and it equals zero if \( \bar{\alpha} = 0 \), (i.e., no defaults if no lending) and \( \bar{\alpha} \) is non-negative by assumption. This term is also increasing in \( \bar{\alpha} \). Therefore, the solution to the associated root finding problem \( f(\bar{\alpha}) - \mathcal{C} = 0 \) is a unique and real-valued.

In partial equilibrium analysis, welfare is measured as the difference between social benefit and social cost. And in competitive markets social benefit is measured by the aggregate revenues while social cost is measured by aggregate costs (Davis & Whinston 1962). It is well known that in order to maximize welfare, the objective of the social planner is to maximize the “joint” profits of firms in an industry. Therefore, we setup the
analogous social planner problem to determine the so called cooperative solution of the
aforementioned game and hence arrive at the “socially optimal” rate of default. The
objective function of the social planner’s problem is given by:
\[
\max_{\{\alpha^t\}_{t=1}^\infty} \sum_{t=1}^\infty \beta^t \left[ r^* \left( 1 - f \left( \sum_{j=1}^N (c + 1) \alpha^t \right) \alpha^t - c \alpha^t - \alpha^t - ((c + 1) \alpha^t - E) \bar{r} \right) \right] \\
s.t.
\]
\[
0 \leq \alpha^t + c \alpha^t \leq E + \bar{K} \rightarrow 0 \leq \alpha^t \leq \frac{E + \bar{K}}{1 + c}
\]
Note that social planner maximizes \( \alpha^t \) not \( \alpha^t \), where \( \alpha^t \) denotes aggregate lending
volume in the microcredit market and the upper case letters are simply the aggregates of
Corresponding lower case variables, i.e., \( E = Ne \) (sum of lender equity) and \( \bar{K} = N\bar{K} \) (sum
of borrowing limits). As argued before, the abovementioned dynamic optimization
problem of the social planner is equivalent to a period by period maximization problem
represented as:
\[
\max_{0 \leq \alpha \leq \frac{E + \bar{K}}{1 + c}} r^* \alpha \left( 1 - f((c + 1)\alpha) \right) - c\alpha - \alpha - ((c + 1)\alpha - E)\bar{r}
\]
In order to determine the “optimal” default rate in the market we solve for aggregate
lending volumes under the cooperative solution. Taking the F.O.C with respect to \( \alpha \), we
get Equation 2:
\[
r^* \left( 1 - f((c + 1)\alpha) \right) - r^* \alpha \left( f'(c + 1)\alpha \right)(c + 1) - (c + 1)(1 + \bar{r}) = 0
\]
The default rates implied by Equation 1 and Equation 2 are not directly comparable. Nevertheless, in Appendix A we use proof by contradiction method to show that default rates are sub optimally high in the presence of intra-firm competition, leading us to the following result:

**Proposition-2A:** *Intra-firm competition among credit unconstrained microfinance institutions results in inefficiently high default rates in equilibrium given a lack of information sharing on defaulters among microfinance institutions, ex-ante adverse selection and ex-post default.*

Intuitively, in a non-cooperative equilibrium, lending volumes are based on considerations for private incentives only and the adverse effects of private actions on aggregate default rates are disregarded. But in the presence of institutional voids, a sole focus on “private” poverty alleviation efforts ignores the negative externalities associated with higher levels of private credit supply on aggregate default rates. The empirical and theoretical literature supports this result. For example, in their empirical work, Fruttero & Gauri (2005) find that NGO location choices are primarily driven by concerns for private benefits as opposed to the developmental considerations of a given community.

Consequently, NGOs ignore the (positive and negative) externalities associated with the so-called private “poverty alleviation” supply curves in order to further organizational objectives, often to the detriment of local communities. Likewise, under very different settings (i.e. allowing borrowing from multiple lenders), McIntosh and Wydick (2005)
and later Guha and Chowdhury (2013) illustrate that microfinance institutions choose to ignore the negative externalities created by their private credit supply curves whilst lending to already indebted borrowers\textsuperscript{25}.

4.3 **Negative Externality of Intra-Firm Competition among Credit-Constrained Lenders**

In the previous subsection we showed that default rates are inefficiently high due of intra-firm competition among microfinance institutions. In this Section we look at a more realistic case, where much like their potential clients, microfinance institutions are also credit constrained, i.e., cannot borrow from a central bank. This is quite true in general but especially so in less developed countries, where microfinance institutions do not possess physical collateral for money lent to clients or significant deposits, so that securing credit from the commercial sector is often not possible. Nevertheless, microfinance institutions do have access to savings in the commercial sector. We also incorporate economies of scale, whereby, all else equal, higher levels of lending reserves lead to lower (marginal) lending costs.

Note that loan defaults have two effects. First clients who choose to strategically default do not repay the promised quoted rate resulting in lost revenue for lenders. Second, and more importantly, lending reserves are also diminished because the original loan

\textsuperscript{25}Given the assumption that probability of default is increasing in the level of debt or the number of creditors, lending to an already indebted borrower increases the loan volume and hence the payoff of a given microfinance institution. But at the expense of imposing a negative externality on the microfinance institution which had lend to the given borrower first.
principal is forfeited in case of default. If microfinance institutions can borrow from the commercial sector, then the lost principal is simply deducted from each period’s payoff. The difference between actual reserves at the end of period and targeted level of reserves are borrowed from the central bank to continue lending at the optimal scale and the cycle continues. However, if microfinance institutions cannot borrow from the commercial sector, then they have to reinvest in their loan reserves each period to ensure that reserves are not depleted to point of exhaustion. Because, in the absence of access to commercial credit, microfinance institutions simply go out of business when lending reserves equal zero. Therefore, in the presence of equilibrium defaults, credit constrained microfinance institutions need to continually reinvest in lending reserves in order to remain a going concern.

We now write down and solve the optimization problem of a representative microfinance institution. The microcredit market is populated with $N$ identical credit-constrained microfinance institutions that seek to maximize the discounted stream of expected profits over an infinite horizon. Microfinance institutions are assumed to have identical initial loan reserves denoted by $k_i$. At the beginning of each period a representative microfinance has to decide how much to lend in the market and how much to reinvest into the loan reserves, given the profit maximizing net lending rate of $r^*$ (characterized in subsection 4.1). As before, $\alpha_i$ represents lending volumes, $f(\cdot)$ is the (aggregate)

\[\text{In the absence of external borrowing the initial loan reserve level represents equity, likely provided by donors for the purpose of provision of microcredit services only and hence its opportunity cost is not included in the analysis.} \]
probability distribution of default as a function of lending volumes (see Proposition 1B), \( c \) is the loan origination or marginal lending cost and \( \bar{r} \) is the net rate of return on the outside investment option. Finally, \( x_l \) denotes the level of reinvestment into the loan reserves each period, whereby \( x_l \) invested in outside investment option at the beginning of each period yields \((1 + \bar{r})x_l\) at the end of period.

In terms of the mathematical formulation of the abovementioned problem, we account for revenue (in its strictest sense) from lending operations in current reward function and capital losses (from defaults) and gains (from reinvestment in lending reserves) in the state equation\(^{27}\). The associated bellman equation is given by:

\[
V(k_i) = \max_{0 \leq \alpha_i, k_i, 0 \leq x_i \leq k_i} \left\{ r^* \left(1 - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \right) \alpha_i - \frac{ca_i}{k_i} + \delta V(k_i) \right\}
\]

s.t.

\[
k_i' = k_i - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \alpha_i + \bar{r}x_i
\]

\[
\alpha_i + c \alpha_i + x_i \leq k_i
\]

In other words, given an initial level of reserves at the beginning of period, lenders optimize with respect to the choice of lending volumes (\( \alpha_i \)) and reinvestment levels (\( x_i \)). The current reward function comprises of revenues from lending operations, i.e., quoted loan rate adjusted for defaults multiplied by loan volume less loan origination costs. Note

\(^{27}\)A simple 2-period model can be used to easily verify the “accounting” identity holds, i.e., separation of revenue and capital accounting is valid.
that compared to the baseline scenario presented in Section 4.2, we incorporate the effects of economies of scale in this formulation, i.e., marginal lending cost declines with increases in the size of loan reserves. The first constraint represents the (simplified) law of motion for loan reserves\(^{28}\). The second constraint is the resource constraint, i.e., outflows on lending activities and investment activities in each period cannot exceed the initial level of loan reserves for a credit constrained lender. It is easy to see that the resource constraint always binds in equilibrium, substituting the resource constraint \(x_i = k_i - \alpha_i + ca_i\) into the maximization problem and law of motion we get:

\[
V(k_i) = \max_{0 \leq \alpha_i \leq \frac{k_i}{k_i + c}} \left\{ r^* \left( 1 - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \right) \alpha_i - \frac{ca_i}{k_i} + \delta V(k_i) \right\}
\]

s.t.

\[
k_i' = k_i - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \alpha_i + \bar{r} (k_i - \alpha_i - ca_i)
\]

Now we look for the symmetric Nash equilibrium of this problem in the steady state, where the unconstrained optimization program is given by:

\(^{28}\) Loan reserves next period are current reserves less the value of loans made out at the beginning of the period and investment in the outside investment option plus loan principal repaid at the end of the period along with the return from investment on outside option, i.e., \(k_i' = k_i - \alpha_i - x_i + (1 - f(\sum_{j=1}^{N} \alpha_j)) \alpha_i + (1 + \bar{r})x_i\), simplifying we get \(k_i' = k_i - f(\sum_{j=1}^{N} \alpha_j) \alpha_i + \bar{r} x_i\).
\[
V(k_i) = \max_{0 \leq \alpha_i \leq \frac{k_i}{1+c}} \left\{ r^* \left( 1 - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \right) \alpha_i - \frac{c \alpha_i}{k_i} \right. \\
+ \delta V \left( k_i - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \alpha_i + \bar{r}(k_i - \alpha_i - c \alpha_i) \right) \left. \right\}
\]

Taking first order condition of the problem with respect to \( \alpha_i \) we get:

\[
\{\alpha_i\}: \ 0 = \ r^* \left( 1 - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \right) - r^* (c + 1) \alpha_i f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) - \frac{c}{k_i} \\
- \delta D V \left( f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + \alpha_i (c + 1) f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + \bar{r} c + \bar{f} \right)
\]

By the envelope theorem condition we know that:

\[
\{k_i\}: DV = \frac{c \alpha_i}{k_i^2}
\]

Substituting the envelope theorem condition into the F.O.C for \( \alpha_i \) we get:

\[
\begin{align*}
& r^* \left( 1 - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \right) - r^* (c + 1) \alpha_i f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) - \frac{c}{k_i} \\
& - \delta \frac{c \alpha_i}{k_i^2} \left( f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + \alpha_i (c + 1) f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + \bar{r} c + \bar{f} \right) \\
& = 0
\end{align*}
\]

Note that in a steady \( k_i' = k_i \) substituting into the law of motion we can show that lending reserves are strictly positive in equilibrium, i.e., \( k_i = f(\sum_{j=1}^{N} \alpha_j (c + \)
\( \alpha_i + \alpha_i + c\alpha_i \geq 0 \). Lastly, substituting the steady state \( k_i \) into the F.O.C for \( \{\alpha_i\} \) we get:

\[
\begin{align*}
    r^* & \left( 1 - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \right) - r^* (c + 1) \alpha_i f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \\
    & - \frac{c}{f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \alpha_i + \alpha_i + c\alpha_i} \\
    & - \frac{\delta c \alpha_i (f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + \alpha_i (c + 1) f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + \bar{r}c + \bar{r})}{(f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \alpha_i + \alpha_i + c\alpha_i)^2} \\
    & = 0
\end{align*}
\]

In Appendix B, we perform some additional algebra. We first sum over optimality conditions of all lenders, thereafter we impose symmetry, i.e., \( \alpha_1 = \cdots \alpha_{i-1} = \alpha_i = \alpha_{i+1} = \cdots \alpha_N = \alpha^* \) to arrive at a symmetric Nash Equilibrium. Lastly, we define \( \sum_{j=1}^{N} \alpha^* = \bar{\alpha} \) as the aggregate lending in this market structure and after some simplifications we get **Equation 3** that implicitly defines the default rates under this market structure:

\[
\begin{align*}
    r^* \bar{\alpha} \left( 1 - f \left( \bar{\alpha} (c + 1) \right) \right) & \left( f \left( \bar{\alpha} (c + 1) \right) + 1 + c \right)^2 \\
    & \frac{r^* (c + 1) (\bar{\alpha})^2 f' \left( \bar{\alpha} (c + 1) \right) \left( f \left( \bar{\alpha} (c + 1) \right) + 1 + c \right)^2}{N^2} \\
    & - \frac{c (c + 1) \delta \left( \bar{\alpha} \right) f' \left( \bar{\alpha} (c + 1) \right)}{N} - (c + \delta) f \left( \bar{\alpha} (c + 1) \right) \\
    & - (c \delta (\bar{r}c + \bar{r}) + c + c^2) = 0
\end{align*}
\]
Similar to the previous subsection, we now derive the default rates implied by the solution to social planner problem. Again, the goal is compare the socially optimal default rates with the default rates in the presence of intra-firm competition. The analogous social problem can be written as:

\[
V(K) = \max_{K} \left\{ r^* \left( 1 - f(\alpha(c + 1)) \right) \alpha - \frac{c\alpha}{K} + \delta V(K') \right\}
\]

Subject to

\[
K' = K - f(\alpha(c + 1)) \alpha + \tilde{r}(K - \alpha - c\alpha)
\]

Where, \( K \) denotes the aggregate initial lending reserves and \( \alpha \) represents the aggregate lending volumes. Each term in the optimization term has already been discussed in detail before, therefore, for sake of brevity we jump to the analysis of the following unconstrained optimization problem:

\[
V(K) = \max_{K} \left\{ r^* \left( 1 - f(\alpha(c + 1)) \right) \alpha - \frac{c\alpha}{K} + \delta V(K - f(\alpha(c + 1)) \alpha + \tilde{r}(K - \alpha - c\alpha)) \right\}
\]

Now we derive the solution to the abovementioned problem in the steady state, taking first order condition with respect to \( \alpha \) we get:

\[
0 = r^* \left( 1 - f(\alpha(c + 1)) \right) - r^* \alpha(c + 1)f'(\alpha(c + 1)) - \frac{c}{K} - \delta Df(\alpha(c + 1)) + \alpha(c + 1)f'(\alpha(c + 1)) + \tilde{r}c + \tilde{r}
\]

The envelope theorem condition gives us:

\[
\{K\}: DV = \frac{c\alpha}{K^2}
\]

Substituting the envelope theorem condition into the F.O.C for \( \{\alpha_i\} \) we get:
\[
\begin{align*}
& r^* \left(1 - f(\alpha(c + 1))\right) - r^* \alpha(c + 1)f'(\alpha(c + 1)) - \frac{c}{K} \\
& \quad - \delta \frac{c\alpha}{K^2} (f(\alpha(c + 1)) + \alpha(c + 1)f'(\alpha(c + 1)) + \bar{r}c + \bar{r}) = 0
\end{align*}
\]

Note that in a steady \( K' = K \) substituting into the law of motion we get: \( K = f(\alpha(c + 1))\alpha + \alpha + c\alpha \geq 0 \). Substituting the steady state level of \( K \) into the F.O.C for \( \{\alpha\} \) we get:

\[
\begin{align*}
& r^* \left(1 - f(\alpha(c + 1))\right) - r^* (c + 1\alpha f'(\alpha(c + 1)) - \frac{c}{(f(\alpha(c + 1))\alpha + \alpha + c\alpha)} \\
& \quad - \delta \frac{c\alpha(f(\alpha(c + 1)) + \alpha(c + 1)f'(\alpha(c + 1)) + \bar{r}c + \bar{r})}{(f(\alpha(c + 1))\alpha + \alpha + c\alpha)^2} = 0
\end{align*}
\]

Details of further simplifications and algebraic manipulations can be found in Appendix C, the final expression characterizing the default rates under the social planner allocation are given in Equation 4 below:

\[
\begin{align*}
& r^* \alpha \left(1 - f(\alpha(c + 1))\right) \left(f(\alpha(c + 1)) + 1 + c\right)^2 \\
& \quad - r^* (c + 1\alpha^2 f'(\alpha(c + 1))(f(\alpha(c + 1)) + 1 + c)^2 \\
& \quad - c(c + 1)\delta\alpha f'(\alpha(c + 1)) - c(1 + \delta)f'(\alpha(c + 1)) - (c\delta(\bar{r}c + \bar{r}) + c) \\
& \quad + c^2)
\end{align*}
\]

Now we can compare the socially optimal default rates under the cooperative equilibrium given intra-firm competition among credit constrained lenders (Equation 4) with the default rates under the non-cooperative equilibrium (Equation 3). Direct comparison...
between default rates under both scenarios is not feasible. Therefore, once again the method of proof by contradiction is employed to show that default rates are inefficiently high in the presence of intra-firm competition. Details of the related algebra are relegated to Appendix D and the final result is summarized in Proposition 2B below:

**Proposition-2B.** Intra-firm competition among credit-constrained microfinance institutions results in inefficiently high default rates in equilibrium given a lack of information sharing on defaulters among microfinance institutions, ex-ante adverse selection and ex-post default.

Before moving onto the next subsection, we want to highlight some important features of the equilibrium default rates under the aforementioned cases. First, note the socially optimal lending volumes and hence the associated defaults rates are independent of the number of competitors in the market under both scenarios, i.e., credit unconstrained or credit constrained lenders. In other words the “size” of the central planner allocation is the same regardless of number of players in the market, obviously smaller shares for each competitor as \( N \) increases. Interestingly, as the number of players in the market increase, competition intensifies and as more resources are pumped into the market, the incentives do default are greater than before leading to a higher rate of resource dissipation. Second, the inefficiencies caused by sub optimally high default rates due to intra-firm competition remains regardless of the organizational structure of the microfinance sector.
4.4 Section Overview

The setting of credit unconstrained profit maximizing behavior is more appropriate if the market is populated primarily by microfinance banks. Whereas, the objective function of credit constrained lenders is more suitable for analyzing markets with non-banking NGO type microfinance institutions. But which market structure leads to higher defaults in equilibrium? And what is the size of the negative competition externality in each case? In order to answer these fundamentally important questions we cannot rely on analytical methods and need to revert to tools for numerical analysis.\(^{29}\)

Figure 5 shows the equilibrium default rates plotted against the number of competitors under different market structures (credit constrained or unconstrained lenders) and scenarios (cooperative or non-cooperative). Since, the number of competitors was taken as given in our model, we solve for equilibrium default rates for different values of \(N\) using the Broyden’s method. These numerical simulations, under reasonable calibrations, corroborate earlier results derived using analytical methods. For example, the equilibrium default rates under the non-cooperative solution are significantly higher compared to the equilibrium default rates under the cooperative solution regardless of market structure as shown in Proposition 2A and 2B. Likewise, consistent with Proposition 1A, figure 5 shows that default rates increase with \(N\), i.e., extent of competition.

\(^{29}\) The analytical proof of proposition 2B is not as elegant as that of proposition 2A. The forthcoming numerical analysis also addresses this deficiency.
Figure 5 Effect of Competition on Equilibrium Default Rates under Different Market Structures

Author: The equilibrium default rates are based on the following model calibrations: net profit maximizing interest rate $r^* = 0.40$ (corresponding gross rate is 1.40), risk free rate $r = 0.025$, marginal lending costs $c = 0.05$, time preference $\delta = 0.99$. The strategic default function $f(\alpha)$ was assumed to be $\frac{\alpha^{15}}{100,000}$ where the denominator denotes market capacity, i.e., total number of potential clients. Broyden’s method routine developed by Miranda and Fackler (2004) was used to solve the nonlinear root finding problems represented in equations 1-4 for different values of $N$.

However, the rate at which defaults increase is much higher in the case of credit constrained lender with economics of scale compared to credit unconstrained lenders. Intuitively, with economies of scale and continual reinvestment into the lending reserves, credit constrained lenders have an additional inventive to disburse loans, leading to higher equilibrium loan reserves and hence higher defaults in the given institutional environment. Moreover, the “size” of the negative competition externality is also larger (both in the absolute sense and the relative sense) in case of a market structure with intra-firm competition among credit-constrained lenders. From a policy perspective, the
numerical analysis clearly highlights that removing credit constraints faced by lenders in microcredit markets is a Pareto optimal intervention from the societal point of view.

We have looked at only two types of lenders in the microcredit market. Credit unconstrained lenders represent large microfinance banks with operations in different regions and credit unconstrained lenders represent small microcredit NGOs often present in only a limited number of areas. Of course, other organizational types, such as the output maximizing microcredit institution analyzed by McIntosh and Wydick (2005), are also present in the microfinance sector, although their share has declined significantly over the past decade due to a paradigm shift from the poverty lending approach towards to the financial systems approach. Nevertheless, McIntosh and Wydick (2005) showed in their paper that profit maximizing and output maximizing microcredit institutions charge identical interest rates in equilibrium. Using this result, it is trivial to show that lending levels and hence default rates will be higher in case of an output maximizing or size maximizing firm subject to a breakeven constraint compared to the cases studied herein30.

However, the analogous social planner allocation in the presence of intra-firm competition among output-maximizing lenders is not apparent because, socially optimal allocations balance the marginal costs and benefits of actions in given settings, whereas in the case of output maximization there is no such tradeoff. Hence, we choose not to

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30 For example, consider the well-known case of a sales maximizing firm originally expounded by Baumol (1959). In this case production is determined at the point where marginal revenue equals zero in contrast to the standard optimality conditions given by the equating marginal revenue to marginal cost. Therefore, as long as marginal costs are non-zero and marginal revenues are declining with production then the sales maximizing firm will produce more than the profit maximizing firm.
explore this market structure further here, although we return to its implication on location choices later.

But are the equilibrium default rates depicted in figure 5 a reasonable approximation of reality? In the case of credit unconstrained, profit maximizing lenders the equilibrium default rates in the presence of intra-firm competition are low for a full blown crisis. However, our model is only concerned with strategic default and does not account for negative shocks that may hamper the ability to repay. The interaction of negative shocks and increased likelihood of strategic default due to intra-firm competition can lead to default rates that are within reasonable bounds of the default rates observed during a repayment crisis in the microfinance sector. The increase in default rates associated with rising competition among credit constrained lenders seem unrealistically large. However, the number of competitors is varied exogenously; therefore, non-positive profits are not inconsistent with short-run maximization problems. At the same time, short-run defaults rates of 60-70% are not uncommon during a full-fledged repayment crisis.

In reality, the microfinance sector is populated with different types of organizations ranging from large profit maximizing microfinance banks to small, liquidity constrained lending operations. Moreover, both types of lenders are neither entirely altruistic (output maximizing) nor motivated by profits only, but located somewhere on a spectrum with profit motives on one end and social mission on the other end. It is well known that the presence of subsidized government sponsored microcredit programs can have adverse
effects on commercial lenders vis-à-vis the interest rate channel, effectively driving the commercial sector out of business. In truth, the implications of the interactions between different types of institutions on default rates in microcredit markets cannot be accurately predicted and in all likelihood the actual default rates will probably fall within the bounds shown in figure 5. Nevertheless, the channels highlighted in the preceding analysis are expected to hold regardless of market structure, although the strength of these effects may vary based on the specific characteristics of each market.

5 Further Analysis

In this Section we extend the preceding analysis to further highlight some interesting results arising from intra-firm competition that are consistent with the stylized facts associated with the development of microcredit sector in less developed countries. In particular, we examine the effects of intra-firm competition for donor funds on equilibrium default rates and look at the location choices of different types of microfinance institutions. Our analysis shows that competition for donor funds leads to further deterioration in repayment rates in the existing institutional environment. A focus on private pay-offs leads to the exclusion of rural markets and excessive concentration in urban markets. This leads to excessively high default rates in the latter leading to resource dissipation and financial exclusion of the former. Both tendencies undermine the original objectives of the microfinance revolution, i.e., sustainable provision of access to financial services.
5.1 Effect of Intra-Firm Competition for Donor Funds on Default Rates

We introduce competition for donor funds in the baseline model described in Section 4.2 in order to look at the effect of donor money on the materialization of microfinance repayment crisis.\textsuperscript{31} We assume that benevolent donors have allocated a fixed (exogenous) amount of donor money for microcredit sector in a given region in each period denoted by $D$, under the assumption that access to microcredit results in poverty alleviation. These donors do not have the capacity to undertake microcredit projects themselves due to the risks, regulatory costs and long term commitments involved in operating a microfinance institution, and are better off disbursing funds to microcredit providers rather than holding on to them for other purposes, i.e., non-distribution constraint.

Outreach or quantity of loan disbursements is widely used as a criterion to evaluate the performance of different types of microfinance institutions and serves as an objective metric of a given lender’s poverty alleviation “effort”. For example Chen et al. (2010) find that funding, national influence, and international recognition all flowed to the largest players. Therefore, the poverty reduction “effort” of a given microfinance institution is judged relative to other competing microfinance institutions based on its relative outreach. And hence donor money is distributed among competing microfinance institutions based on relative outreach. In other words, donor money is a “prize” that lenders in a given market vie for with “outreach effort”, where the payoff of the $i^{th}$ lender

\textsuperscript{31} Identical results hold for credit constrained profit maximizing lenders with economies of scale but with considerably tedious algebra.
is given by \( D_i = \frac{Da_i}{\sum_{j=1}^{N} \alpha_j} \). It is easy to see that this payoff function introduces another channel of strategic interdependence into the baseline model, whereby a given microfinance institution’s share of the so called “prize” is decreasing in the “outreach effort” of competing lenders, i.e., \( \frac{\partial D_i}{\partial \alpha_j} < 0 \).

Note that the amount of donor funds allocated to the microfinance sector is assumed to be exogenously fixed. However, the distribution of these funds among competing institutions is endogenous. Moreover, in contrast to Aldashev & Verdier (2010), the competition for donor money in this paper takes place through “on-project effort” as opposed to “off-project effort”. This feature makes our results potentially more interesting. As before, microfinance lenders are assumed to be rational payoff maximizing agents with an infinite horizon. Given the results of the previous Section, the equilibrium default rate with competition for donor money is defined by the solution to the following period by period optimization problem:

\[
\text{Max}_{0 \leq \alpha_i \leq \frac{e+c}{1+c}} \left( r^* \left( 1 - f \left( \sum_{j=1}^{N} (c + 1)\alpha_j \right) \right) \alpha_i - c\alpha_i - \alpha_i - (c + 1)\alpha_i^t - e \right) + \frac{D \alpha_i}{\sum_{j=1}^{N} \alpha_j}
\]

The first order condition is given by:

\[
r^* \left( 1 - f \left( \sum_{j=1}^{N} (c + 1)\alpha_j \right) \right) - (c + 1)f^t \left( \sum_{j=1}^{N} (c + 1)\alpha_j \right) r^* \alpha_i - (c + 1)(1 + \bar{r})
\]

\[+ D \frac{\sum_{i \neq j} \alpha_i}{(\sum_{i=1}^{N} \alpha_i)^2} = 0\]
We look for a symmetric Nash Equilibrium, such that $\alpha_1 = \alpha_{i-1} = \alpha_i = \alpha_{i+1} \ldots \alpha_N = \alpha^*$, substituting this into the first order condition and summing over $N$ we get:

$$Nr^*(1 - f((c + 1)(N\alpha^*)) - N\alpha^*r^*f'(((c + 1)(N\alpha^*)))(c + 1) - N(c + 1)(1 + \bar{r})$$

$$+ \frac{D(N - 1)N\alpha^*}{(N\alpha^*)^2} = 0$$

Let $N\alpha^* = \bar{\alpha}$ denote aggregate lending volume. Substituting it into the expression above we get Equation 5 which implicitly pins down the aggregate default rates in this case:

$$r^*(1 - f((c + 1)\bar{\alpha})) - \frac{\bar{\alpha}r^*}{N} f'((c + 1)\bar{\alpha})(c + 1) - (c + 1)(1 + \bar{r}) + \frac{D(N - 1)}{N\bar{\alpha}} = 0$$

Now we can also write down the analogous social planner problem:

$$\max_{0 \leq \alpha \leq \frac{E + \bar{\alpha}}{1 + \bar{\alpha}}} \left( r^* \left( 1 - f((c + 1)\alpha) \right) - c\alpha - \alpha - ((c + 1)\alpha - E)\bar{r} + D \right)$$

Note that there is no intra-firm competition for donor funds in a cooperative equilibrium because the amount of donor money allocated to the microfinance sector (as a whole) is exogenously fixed independent of outreach effort. Obviously, the first order condition associated with the abovementioned optimization problem is identical to Equation 2 derived in Section 4.2, i.e., in the social planner allocation donor money has no effect on equilibrium default rates since each lender simply gets an equal share of the prize, i.e., $\frac{D}{N}$.

Formally, it is straightforward to show that competition for donor money results in sub-optimally high default rates. Note that the default rate implied by the analogous social planner problem with a fixed donor inflow of $D$ is $f((c + 1)\alpha)$, identical to Equation 2.
in Section 4.2. Also recall that in Proposition 2A we showed that $\bar{a} > \alpha$, where $\bar{a}$ is lending volume with intra-firm competition (without donor inflows). We can equate Equation 1 and Equation 5 since the LHS is zero, after some simplifications we get:

\[
[f((c + 1)\bar{a}) - f((c + 1)\bar{a})] + \left(\frac{c + 1}{N}\right)[\bar{a}f'((c + 1)\bar{a}) - \bar{a}f'((c + 1)\bar{a})] = \frac{D(N - 1)}{r\cdot N\bar{a}}
\]

Now we compare $\bar{a}$ and $\bar{a}$. Note that the LHS is always positive since $N > 1$ by definition. Therefore, if $\bar{a} = \bar{a}$ then all the terms on the RHS cancel out. Whereas, if $\bar{a} > \bar{a}$, then since $f' > 0$ by Proposition 1B and $f'' > 0$ by assumption then the RHS is always negative. Consequently, it must be that $\bar{a} > \bar{a}$ and hence $f((c + 1)\bar{a}) > f((c + 1)\bar{a}) > f((c + 1)\alpha)$, i.e., competition for donor money leads to sub-optimally high default rates. Intuitively, although the marginal revenue from each additional loan declines below the marginal cost, microfinance institutions continue to lend given the benefits of the share of donor money.

**Proposition 3:** Intra-firm competition for donor money, distributed among competing lenders on the basis of relative outreach, results in inefficiently high default rates in equilibrium given a lack of information sharing on defaulters among microfinance institutions, ex-ante adverse selection and ex-post default.

Clearly, competition for donor money is suboptimal because lenders purse higher lending volumes (i.e., larger lending reserves) as a goal in itself, in order to gain a larger chunk of
the donor “prize” money. Although not considered here, larger lending volumes (hence larger reserves) also come with additional benefits including economies of scale, prestige and reputation which can be used to attract further funding. However, these types of “credit push” incentives have often led to the oft discussed phenomena of double dipping in the microfinance sector. Whereby, microfinance institutions knowingly lend to already indebted and marginal clients resulting in the over indebtedness and eventually wide scale default, similar to the 2010 Indian microfinance crisis (Guha & Chowdhury 2013). We once again use numerical simulations to highlight the effect of donor money inflows on equilibrium default rates in the aforesaid institutional settings.

Figure 6 confirms earlier claims that large inflows of donor money can lead to an exponential increase in default rates and at times even a full blow repayment crisis in the given institutional environment. For example, if donor inflows in a given period amount to approximately 1% of total loan demand then default rates range from 50-60%, very close to the threshold of a default crisis. Moreover, increasing donor inflows are also likely to draw in additional competitors in expectation of higher future profits, leading to further erosion of dynamic repayment incentives and hence higher default rates.
Figure 6 Effect of Competition for Donor Funds on Equilibrium Default Rates

Author: The equilibrium default rates are based on the following model calibrations: net profit maximizing interest rate $r^* = 0.40$ (corresponding gross rate is 1.40), risk free rate $r = 0.025$, marginal lending costs $c = 0.05$ and $D = 100$ and 1000 corresponds to 0.1% and 1% of total credit demand (100,000), respectively. The strategic default function $f(\alpha)$ was assumed to be $\frac{\alpha^{1+\epsilon}}{100,000}$, where the denominator denotes market capacity, i.e., total number of potential clients. Broyden’s method routine developed by Miranda and Fackler (2004) was used to solve the nonlinear fixed point problems represented in equations 1 & 5 for different values of $\alpha$.

Note that we are not trying to argue that donor money is inherently bad, but merely stating that in the absence of information sharing on defaulters among competing microfinance institutions, polices seemingly designed to benefit the microcredit sector can actually have the opposite effect. The conclusions drawn from proposition-3 also fall in line with the stylized facts associated with a microfinance crisis. For example, Viada & Gaul (2011) documented that increasing donor inflows (and investment in general) was recorded leading up to a microfinance crisis in many countries like Bosnia, Uganda, India etc., reaffirming the central theme of this, i.e., under certain circumstances more is actually less!
5.2 Effect of Intra-Firm Competition on the Location Choices of Lenders

Continuing with the analysis of the supply side, we extend the preceding analysis to highlight the adverse effects of intra-firm competition on the location choices of lenders in this subsection. The correlation between rural agricultural households and poverty is markedly strong in South Asia; therefore, interventions in rural markets are key to poverty alleviation. However, geographically, microfinance service providers are increasingly concentrated in large urban cities in less developed countries (Oxford Policy Management 2006 and International Finance Corporation & KfWBankengruppe 2009). For example, the percentage of urban clients in the microfinance industry portfolio of Pakistan increased from approximately 30% in 2005 to 44% in 2012 (Pakistan Microfinance Network Industry Review 2012). In some African markets the rural and urban divide is even larger. The schism between provision of microfinance services in rural and urban areas in less developed countries becomes wider if government funded public microcredit programs are excluded from the analysis. This increasingly uneven distribution of commercial microfinance services between rural and urban areas is not optimal from the societal point of view.

Firstly, as highlighted in Proposition 1A and subsequently, in the absence of information sharing on defaulters an increase in the number of lenders in a given market dilutes dynamic repayment incentives leading to a higher likelihood of strategic default. Likewise, Guha & Chowdhury (2013) have shown that with an increase in number of lenders, microfinance clients are more likely to engage in double dipping, resulting in
over indebtedness and eventually wide scale default. In a nutshell, excessive concentration in urban areas dilutes dynamics repayment incentives whilst the tendency to “push” credit in face of competitive pressures results in over-indebtedness. Together both factors have contributed towards the materialization of frequent microfinance crisis over the past decade in countries like Bosnia, Uganda, Pakistan, India and Nicaragua.

Secondly, the exclusion of rural areas undermines the original objectives of microfinance, i.e., providing access to credit to the financial excluded sector. Moreover, rural poor are often the largest component of poor and vulnerable populations in less developed countries. Therefore, “real” economic development is not possible without overcoming the financial exclusion of the rural poor. For instance, access to credit can help poor farmers, often engaged in subsistence farming based on traditional labor-based farming methods, overcome credit constraints associated with technology adoption. And increases in income are often a harbinger of agricultural mechanization, which eventually leads to structural change from an agriculture based economy to an industrialized economy. Moreover, at the very least, improvements in economic opportunities in rural areas will curtail excessive migration into sprawling urban centers of less developed countries, along with its negative repercussions for example increase in crime rates, pollution, squatter settlements etc. Likewise, compared to urban poverty alleviation, rural poverty alleviation has larger spillover effects due to the increased demand of secondary goods in the often isolated rural local economies.
However, lending costs in rural areas are unsurprisingly higher compared to lending costs in urban areas for several reasons. First, due to limited infrastructure facilities in rural areas, the management of microcredit operations is typically done from offices located in urban areas. Likewise, rural areas have a poor transportation and communications network. Therefore, lending costs associated with vetting loan applications, delivering credit, collecting payments and monitoring clients increase with distance from urban centers. Second, geographically, rural clients are spread over a larger area compared to urban clients and delivering microfinance services at several, small, scattered locations is more costly compared to urban clients concentrated in densely populated cities. Consequently, given the labor intensive operations of microfinance institutions, more clients can be served per worker in urban areas compared to rural areas due to aforementioned factors. However, on the positive side, Imai et al. (2012) find that information costs are usually lower in agriculture based microloans in rural areas compared to non-agricultural microenterprises in urban centers.

Nevertheless, despite the abovementioned pros and cons of lending in rural and urban microcredit markets, one can clearly see a noticeable trend in the commercial microfinance sector of less developed countries, i.e., a marked focus on urban microcredit markets at the expense of rural credit markets. This also increases lack of diversification.

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32 This does not hold for all countries. For example, in a densely populated country like Bangladesh microcredit institutions have a strong presence in rural areas. However, in more geographically diverse countries like Pakistan, Uganda and Kenya the rural-urban dichotomy is clear. For example in Pakistan, microfinance providers are predominantly present in the metropolitan cities of the affluent provinces, i.e., Punjab and Sind. Whilst, ignoring the less developed rural provinces of KPK and Baluchistan, although, both the extent and depth of poverty is higher in the later.
in the loan portfolio of microfinance institutions and increases their vulnerability to external shocks. Is intra-firm competition responsible for this adverse geographical distribution? And is this distribution suboptimal? In order to answer these questions, we use simple game theoretic arguments. The following analysis, although not as rigorous as some of the earlier work presented above, nevertheless, it promises to offer logical and intuitive insights into the location choices of different types of lenders.

We assume there are only two microcredit markets, i.e., rural and urban. The loan origination or marginal lending costs are higher in the rural markets compared to the urban markets, i.e., $c^{rural} > c^{urban}$. Both markets are identical in all other aspects, i.e., ex-ante adverse selection with ex-post default, hence, the profit maximizing interest rate ($r^*$) is assumed to be equal in both markets.

We begin our analysis with the simplest case of an altruistic microfinance institutions, i.e., client (output) maximizer as in McIntosh & Wydick (2005). It is a commonly held view that the adverse geographical distribution of microfinance institutions is driven by the rise of commercially oriented microfinance institutions rather than socially motivated

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33 Chen et al. (2010) find that in Pakistan and Morocco it had been a common practice among some lenders to follow other lenders into local markets in order to lend to the same clientele. Since, first movers are the first to screen and train new borrowers whereas later arrivals can skip over these up-front preparatory costs and significantly lowering client acquisition costs.

34 I hope to further develop the decision making process that goes into the location choices of lenders rigorously in future work and test it empirically with branch location data from Pakistan. This will basically require optimization of an integral over a continuum of microcredit markets differing in marginal lending costs in addition to channels of strategic dependence highlighted in this paper.
lenders. This is not entirely true. In fact it is easy to see that an output maximizer will always choose to enter the cheaper urban markets.

The objective of a socially motivated client maximizer is to simply maximize number of clients subject to a resource constraint. Therefore, the production function of a client maximizer is simply given by \( e^{rural} \alpha^{rural} + e^{urban} \alpha^{urban} \). Since clients in urban and rural markets are perfect substitutes as far as loan volume is concerned, it is trivial to show that a rational lender will always choose to lend in the cheaper market, i.e., \( \alpha^{rural} = 0 \) as long as \( e^{rural} > e^{urban} \).

Intuitively, most altruistic microfinance institutions are funded by donors and, as mentioned before, outreach is a commonly used metric to judge the “poverty alleviation effort” of competing lenders. Therefore, facing competitive pressures for securing additional donor funds, altruistic lenders are even more likely to focus lending operations in cheaper urban markets. Because, serving the relatively expensive rural markets will lead to a reduction in loan volume given a fixed resource constraint. In a non-cooperative equilibrium, this in turn leads to a decline in the share of donor money received next period, which necessarily results in lower lending volumes in future. The cycle continues, until altruistic lenders focusing on rural markets eventually go out of “business”\(^{35}\). As rational agents, altruistic microfinance institutions realize the negative repercussions of lending in rural markets and focus lending activities in urban centers. As discussed

\(^{35}\) We assume founders of altruistic lenders get some non-monetary utility from providing credit to the poor for example social prestige, “warm-glow effect” etc., therefore, always prefer to continue operations.
before, an overconcentration of micro-lenders in urban centers dilutes the dynamic incentives associated with loan repayment, leading to inefficiently high default rates and at times even a repayment crisis. Adding an additional break-even constraint complicates the preceding analysis, nevertheless the conclusions still hold especially if marginal lending costs in rural areas are significantly higher.

The stylized facts also support the abovementioned arguments. For example, in Pakistan the widening gap between rural and urban borrowers in the industry portfolio has coincided with an increase in the market share of non-profit microcredit NGOs from 17% in 2005 to almost 34% in 2007. Similar trends have been observed in other less developed countries, where microfinance NGOs have consistently followed an intensive growth strategy, i.e., vied for growth in existing markets and products without expanding into new markets or new products. In fact, these trends have led several economists and practitioners to heavily criticize the rise of the so called “NGO industry” in general and microcredit NGO sector in particular e.g. see Dichter and Harper (2007) and Dichter (2010).

However, in the case of profit maximizing microfinance institutions, arguments for a rural-urban schism are less crisp because profit maximizing lenders are primarily interested in profits, not output. And given the negative externality of intra-firm competition, profit maximizing microfinance institutions are more likely to move to rural markets if benefits of doing so outweigh the costs. This involves a continuous assessment
of expected profit differentials in both types of markets. But if the relative payoffs from donor money are large enough (as shown in Proposition 3), then the arguments presented above clearly hold and will lead to a rural-urban divide.

In order to simplify the analysis we assume that profit maximizing lenders can only enter one market\(^{36}\). This is a reasonably justifiable assumption given that fixed costs of entry may be high, lenders might lack the capacity to enter multiple markets or simply with a large number of potential markets each lender can only serve a limited number of markets. To highlight the underlying mechanisms we look at a simple example with two identical lenders.

Let \( \pi_{\text{rural} \times \text{rural}} \) denote profits of a given microfinance institution if both enter the rural market. Likewise, \( \pi_{\text{urban} \times \text{urban}} \) denote profits of a given microfinance institution if both enter the urban market. Given that the profit maximizing interest rate \((r^*)\) and the aggregate strategic default function are identical in both markets but \( c_{\text{rural}} > c_{\text{urban}} \), it is straightforward to use results presented in Section 4.2 to show that \( \pi_{\text{urban} \times \text{urban}} > \pi_{\text{rural} \times \text{rural}} \). Finally, let \( \pi_{\text{urban} \times \text{rural}} \) represent profits of a microfinance institution that enters the urban market, given its competitor enters the rural market; and let \( \pi_{\text{rural} \times \text{urban}} \) represents profits of a microfinance institution that enters the rural market, given its competitor enters the urban market. Again we can use Proposition 2A to arrive at the conclusion that \( \pi_{\text{urban} \times \text{rural}} > \pi_{\text{urban} \times \text{urban}} \) due to the negative externality of

\(^{36}\) Note that in the case of output maximizing lender it was clearly never optimal to enter both markets.
intra-firm competition. Of course this implies that $\pi^{urban,rural} > \pi^{rural,rural}$. Under the assumption that $\pi^{urban,urban} \geq \pi^{rural,urban}$, it can be easily shown that both lenders enter the urban market in a Nash equilibrium. To see this note that the abovementioned results can be represented in the following payoff matrix:

### Table 2 Payoff Matrix of Location Choice Game

<table>
<thead>
<tr>
<th>Players</th>
<th>Lender-2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lender-1</strong></td>
<td><strong>Rural</strong></td>
</tr>
<tr>
<td>Rural</td>
<td>$(\pi^{rural,rural}, \pi^{rural,rural})$</td>
</tr>
<tr>
<td>Urban</td>
<td>$(\pi^{urban,rural}, \pi^{rural,urban})$</td>
</tr>
</tbody>
</table>

Each row in table 2 represents the strategy choices of lender-1 and each column represents the strategy choices of lender-2, whereas the first number in the brackets denotes the payoff of lender-1 and second number denotes the payoff of lender-2. It is easy to note that $(\pi^{urban,urban}, \pi^{urban,urban})$ is the unique Nash equilibrium of this game. For instance, if lender-2 decides to enter the rural market than lender-1 obviously enters the urban market because $\pi^{urban,rural} > \pi^{urban,urban} > \pi^{rural,rural}$ by Proposition 2A. And if lender-2 decides to enter the urban market then lender-1 is still better off entering the urban market since $\pi^{urban,urban} \geq \pi^{rural,urban}$ by assumption. Given the game is symmetrical; we conclude that entering the rural market is the dominant strategy of each player.
Note that \((π^{urban,rural}, π^{rural,urban})\) or \((π^{rural,urban}, π^{urban,rural})\) is the cooperative or social planner allocation. Therefore, the non-cooperative equilibrium is not Pareto optimal as long as \(π^{urban,rural} - π^{rural,urban} + (π^{rural,urban} - π^{urban,rural}) > 0\), i.e., the positive value of the first bracketed term dominates the negative value of the second bracketed term. Intuitively, the social planner maximizes total welfare by assigning different lenders to different locations thereby minimizing the negative externality of intra-firm competition. Obviously, this cannot be done in a decentralized solution due to a sole focus on private incentives, resulting in exclusion of the rural poor from access to credit along with sup optimally high default rates in urban areas.

Equivalently, this strategic interaction among competing lenders can be modeled as a two stage, simultaneous move game. Here, in the first stage each lender (simultaneously) decides which market to enter and optimal lending levels are determined in the second stage. Using sequential rationality it is straightforward to see that no lender chooses to service the rural microcredit markets. Therefore, all lenders enter the cheaper urban markets. Identical results for the abovementioned location choice games can be derived for multiple lenders and markets.

The equilibrium of the game tree depicted below can be solved using backwards recursion. While, the optimal geographic coverage can be retrieved from the solution to

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37 We simply compute the total payoffs from the cooperative solution and the non-cooperative solution. Subtracting the latter from the former yields a positive number, i.e., total payoff from the cooperative solution is greater than total payoff from the non-cooperative solution because \(π^{urban,rural} > π^{urban,urban}\) by proposition 2A.
the social planner problem which involves equating the marginal revenue from each type of market to the marginal cost of the cheapest market. Assuming an interior solution, we get non-zero lending in rural markets in the cooperative equilibrium, although, lending volumes are higher in urban markets compared to rural markets due to the lower marginal costs in the former.

However, due to strategic interdependencies, the non-cooperative equilibrium always entails a sub optimally high concentration of lenders in the cheaper urban markets and no lending in the costly rural markets. The results described above are summarized below:
**Proposition-4:** Given that marginal lending costs are higher in rural markets compared to urban markets, an altruistic output maximizer will never enter rural markets due to efficiency considerations.

While in the presence of intra-firm competition among profit maximizing lenders, servicing the cheaper rural markets is a dominated strategy if $\pi^{\text{urban,urban}} \geq \pi^{\text{rural,urban}}$ and it is also sub-optimal given that $(\pi^{\text{urban,rural}} - \pi^{\text{urban,urban}}) + (\pi^{\text{rural,urban}} - \pi^{\text{urban,urban}}) > 0$. Hence, distribution of donor money among competing lenders on the basis of relative outreach further exacerbates the schisms between rural-urban lending.

Several simplifying assumptions were made to keep the analysis as straightforward as possible. It would be interesting to see if identical results can be derived from a more general model with several lenders and an entire spectrum of microcredit markets, such that profit maximizing lenders may enter multiple markets simultaneously. But for the time being, Proposition 4 highlights that market mechanisms to solve problems of poverty alleviation are plagued with incentive problems. Whereby, altruistic, client maximizing lenders decide to ignore the rural poor due to simple efficiency based considerations and serving the rural poor is a dominated strategy for the (more maligned) commercial lenders. These location choices lead to a sub-optimally high concentration of lenders in cheaper urban markets resulting in dilution of dynamic repayment incentives, double dipping (client over-indebtedness) and eventually high default rates. Whereas, exclusion of the rural poor from access to credit not only undermines the original
objectives of microfinance movement but retards the speed of structural change and economic growth.

6 Conclusion

6.1 Overview and Summary of Findings

Microfinance plays a key role in the poverty alleviation strategy of international development agencies. Moreover, an array of donor funded institutions is increasingly the preferred option for microcredit interventions in less developed countries. In this paper we have extended the burgeoning literature examining the effects of the industrial organization of microfinance sector on poverty alleviation (Guha & Chowdhury 2013 and McIntosh& Wydick 2005) and the adverse consequences of competition among NGOs for donor money on poverty alleviation (Fruttero & Gauri 2005 and Aldashev & Verdier 2010) to highlight problems with the existing structure of the microcredit markets.

In summary, we first established that no information sharing on defaulters among competing microfinance institutions is the unique (sub-optimal) Nash equilibrium in competitive microcredit markets in less developed countries. Second, we developed a simple model of strategic default by borrowers to show that probability of ex-post default is a function of the number of competing lenders in a region and “credit rationing” as measured by the ratio of aggregate lending reserves to loan demand. More specifically, we proved that the probability of strategic default increases with the number of competitors and lending volumes in a given microcredit market via the dilution of the
dynamic incentives of loan repayment. Based on these findings we specified the behavior of aggregate default function \( f(.) \) in microcredit markets. Thereafter, building on the seminal work of Stiglitz&Weiss (1981) we demonstrated that in the presence of ex-ante adverse selection and strategic default, there exists a unique profit maximizing interest rate \( r^* \) that is independent of lending levels. Because in a symmetric Nash equilibrium raising interest rates above \( r^* \) leads to lower profits due to the negative effects of adverse selection and in the presence of excess demand, lowering interest rate below \( r^* \) obviously results in lower profits.

Armed with the equilibrium interest rate and the aggregate default function, we formulated an infinite horizon, dynamic optimization problem to capture the objective function along with the relevant constraints of credit unconstrained lenders and credit constrained lenders with economies of scale. We solved for the default rates in a symmetric Nash equilibrium in each case and compared it with corresponding default rates from the analogous social planner problem to prove that intra-firm competition results in inefficiently high default rates. Moreover, we find that the equilibrium default rates in a market with credit constrained lenders are significantly higher compared to equilibrium default rates in a market with credit unconstrained lenders.

Subsequently, we introduced competition for donor funds among lenders through relative outreach and proved that increasing flows of donor funds lead to higher default rates regardless of the of lenders objective functions in microfinance markets. Lastly, we
extended the model to include multiple microcredit markets that differ in marginal lending costs, and show that competition among lenders leads to an over emphasis on urban areas (where transaction costs are assumed to be lower compared to rural areas) at the cost of the exclusion of rural areas, resulting in financial exclusion of rural poor on one hand and sub optimally high default rates in urban areas on the other. Increases in the level of donor funding towards the microfinance sector exacerbate the aforementioned negative effects of location bias in both the short and long run, especially in the case of output maximizing altruistic lenders.

In a nutshell, the abovementioned results are based on the simple yet powerful idea that microfinance institutions have a private supply curve of “poverty alleviation effort” that does not account for the positive externalities of serving financially excluded microcredit markets. Likewise, in the absence of information sharing on defaulters, the private supply curve of “poverty alleviation effort” do not account for the negative externality imposed on competing lenders, resulting in inefficiently high default rates and overconcentration in urban markets. And it is well known that in a competitive equilibrium there is underproduction of goods with positive externalities and overproduction of goods with negative externalities. At the same time, competition for the ever increasing inflows of donor funding into the microfinance sector further exacerbates these inefficiencies. Of course we are not the first ones to point this out in the context of development economics.
Empirical evidence presented in Fruttero & Gauri (2005) highlight that developmental interventions by NGOs are driven by private organizational concerns as opposed to the developmental needs of recipient communities. Consequently, NGO project choices do not reflect community needs or take into consideration externalities of existing developmental projects but are often driven by a desire to secure donor funds or other organizational goals. Guha & Chowdhury (2013) highlight another important channel whereby intra-firm competition results in “credit push” such that microfinance institutions willingly lend to already indebted clients. This double-dipping equilibrium eventually leads to soaring default rates and repayment crisis like the one witnessed by the Indian microfinance sector in 2010. Similarly, Aldashev & Verdier (2010) prove that entry of additional NGOs into the so-called “development market” imposes a negative externality on existing NGOs by reducing the return on existing fund-raising efforts. Consequently, in a symmetric Nash equilibrium all NGOs increase fund raising efforts.

This increase in competition for donor funds is potentially inefficient because resources are increasingly diverted from project related activities towards fundraising activities, diluting the actual impact of NGOs. Therefore, to a large extent, our conclusions mirror the findings of prior literature albeit under very different settings and assumptions. Nevertheless, it would be interesting to see the how intra-firm competition in the given institutional environment effects investment in lending technologies that have the

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38 For example, a village with an existing microfinance institution will benefit more from an educational project like a school or training center as opposed to another microfinance institution. However, often NGO project and location choices do not reflect these externalities but driven by selfish organizational concerns.
potential to reduce the lending costs. Similarly, it would be worthwhile to look at market
dynamics if lenders are assumed to reinvest profits into existing lending reserves in order
to maximize the size of lending reserves. Lastly, the association between different
measures of poverty incidence and microcredit institution’s branch location choices can
be studied, after controlling for covariates, to empirically test the validity of the results
presented in this Chapter.

6.2 Some Policy Prescriptions

Despite the support of millions of dollars and the neoliberal theory of economic
development, microfinance has failed to live up to its claim of sustainable poverty
alleviation via market mechanisms. Therefore from a policy perspective, our analysis
calls for a complete paradigm shift in the current policy prescriptions meted out to the
microfinance sector. We conclude the paper by presenting policy recommendations to
mitigate some of the adverse effects of the abovementioned market failures. Thereafter,
we address some of the inherent fallacies in the existing microfinance narrative and
suggest a way forward.

Firstly, the microfinance sector has remained largely unregulated in most developing
countries under the pretext the market based solutions are by design the best solution to
the problem of lack of access to credit. The preceding analysis highlights that this
approach needs to change and microcredit lenders should be regulated in order to reduce
or at least manage the negative effects of intra-firm competition, since competition can
introduce new market dynamics that are not always easy to see. Policies could include subsidies for lenders operating in rural areas to reduce the profit differentials between rural and urban markets. Interestingly, globally the financial sector is best characterized by oligopolistic or monopolistic competition. Therefore, creating similar incentives for local microcredit monopolies by offering regional licenses does not seem like a bad idea. In a nutshell, market mechanisms for provision of microfinance services have not worked in the past hence state intervention is necessary to prevent further misallocation of valuable resources.

Secondly, the onus of financial inclusiveness has fallen entirely on practitioners, but donors need to start taking more responsibility towards the agenda of financial inclusiveness for microfinance to succeed. In the past donors have been content with pumping funds into the sector without being cognizant of the adverse incentives of distributing donor funds based on hard rules of operational efficiency (cost minimization) and effectiveness (relative outreach). Donors clearly need to focus on coming up with ways to incentivize provision of microcredit services for the financial excluding, even though, this may entail larger outlays on monitoring and evaluation of funded lenders and a transition from hard to soft funding allocation rules. More importantly, donors need to realize that microfinance is not “the” solution to poverty and balance contributions towards the microfinance sector with other philanthropic interventions. Unfortunately, donors are often culpable of bringing in “magic bullets” by funneling large amount of resources into new ideas whilst ignoring past projects. This has forced practitioners in the
past, which obviously comprises of both sincere and opportunistic individuals, to jump on the microfinance bandwagon and the ensuing intra-firm competition has created adverse incentives that have resulted in unnecessarily high default rates.

Lastly, all else equal, any meaningful reduction in the probability of ex-post default is dependent upon improvements in the underlying institutional environment in less developed countries. Therefore, more than the establishment of centralized credit bureaus, this entails better contract enforcement mechanism and legal systems to curtail ex-post default. Unfortunately, institutional change is neither easy nor swift due to vested interests and lack of political will. However, given that the speed of growth in the microfinance industry has outstripped the capacity of microcredit lender’s information systems, investments in information systems are necessary. Moreover, over time these investments have the potential to reduce the marginal cost of sharing information on defaulters among competing lenders to effectively zero.

In a nutshell, there are no magic bullets to the multifaceted and complex problem of poverty and microcredit is merely just another piece of this puzzle. Therefore, development policy needs to be multidimensional and based on the scientific approach of trial and error. This requires a dispassionate analysis of polices and mechanisms in addition to a deep understanding of the context of developmental problems. It is only through a firm commitment to this type of continuous experimentation and learning that
we can make a dent in poverty. Otherwise, we may well remain stuck trying to solve the wrong problem!
Chapter 2

Endogenous Price Fluctuations in a Vertically Linked Agricultural Value Chain: A Simple Model and Empirical Evidence from the Pakistan Poultry Sector

1 Introduction

Fluctuations in prices of agricultural products have a large impact on the welfare of consumers and farmers, especially in less developed countries characterized by heavy dependence on domestic production of food-based commodities and imperfect or even nonexistent risk-sharing markets (futures contracts and crop insurance etc.). Despite, the emergence of a vast empirical and theoretical literature on the dynamics of agricultural product prices in the aftermath of the 2008 food price crisis, many important research questions remain unresolved. In particular, one finds significant disagreement among economists regarding the mechanisms that drive often large fluctuations in agricultural commodity prices over time, in spite of relatively stable fundamentals. Given the relatively inelastic demand for agricultural products (particularly food-based commodities), even small changes in supply can lead to large fluctuations in prices (Tomek 2000). Compared to non-agricultural commodities, the analysis of the supply of agricultural products is greatly complicated by interlinked value chains, uncertainty caused by the biological nature of the production process and time lags between the decision to produce and the marketing of output.
At the expense of generalization, theories of commodity price fluctuations can be broadly classified into two categories. On the one hand, the theory of exogenous price fluctuations developed by Muth (1961), Deaton & Laroque (1996, 1992) and Miranda & Glauber (1993) etc., among others, argues that fluctuations in agricultural commodity prices are a result of exogenous factors that affect farm supply, for example, random weather and disease shocks or seasonality of production. The competitive storage model and its different variants, extensively reviewed by Gouel (2012), is the workhorse behind the development of this theory. In these models, consistent with the rational expectation hypothesis, the distribution of shocks conditional on information available in the current period is assumed to be common knowledge. Therefore, prices fluctuate around the long-run equilibrium level due to random shocks and not any systematic changes in farmers’ behavior. Though, very much within the tradition of modern neoclassical economics, however, in contrast to real world prices, which are usually characterized by irregular fluctuations, high first order autocorrelation, positive skewness and small kurtosis, prices generated from these models usually exhibit low first order autocorrelation, high skewness and kurtosis (Mitra and Boussard 2012)\(^39\).

On the other hand, the theory of endogenous fluctuations can be traced back to the early work of Ezekiel (1938) on cobweb cycles. In cobweb models, expectations of future prices are based on past prices (i.e., backward looking expectations) and lead to periods

\(^{39}\) High autocorrelation is possible in rational expectations competitive storage models, whereby intertemporal arbitrage through storage produces autocorrelation, and it can be made quite high by assuming appropriate parametric specification of the cost of storage and by using a framework that allows for multiple periods during a standard production cycle.
of oversupply and undersupply, resulting in periodic cycles of low and high prices, respectively. Yet, with linear farm supply and demand functions, dynamics in a simple cobweb model are limited to three unrealistic scenarios: rapid convergence to a steady-state, two-period cycles of high-low prices (negatively auto-correlated prices), and explosive oscillations (divergence that results in negative or infinite prices). Clearly, none of these patterns fits the stylized facts associated with real world price data.

However, more recent refinements of the original cobweb model (Finkenstadt and Kuhbier 1992, Boussard 1996 and Hommes 1998), commonly known as chaotic cobweb models of agricultural markets, have resuscitated interest in the theory of endogenous price fluctuations. This stream of literature addresses key shortcomings of the original cobweb model (i.e., negatively auto-correlated prices and convergence to equilibrium) by introducing nonlinearities into the demand/supply functions without changing the essential features of the original model, i.e., backward looking expectations and production lags (Lichtenberg & Ujihara 1989, Day and Hanson 1991, Hommes 1994 and Finkenstädt 1995). As a result, unlike simple cobweb models, the price trajectories derived from chaotic cobweb models display irregular and random behavior, consistent with the observed price fluctuations in real world data. Unfortunately, in contrast to real world data, these price trajectories are often typified by negative skewness and low first order autocorrelation.

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40 Werndl (2009) defines chaos as “chaotic systems are deterministic systems showing irregular, or even random, behavior and sensitive dependence to initial conditions,” which “means that small errors in initial conditions lead to totally different solutions.”
Given the adverse sociopolitical ramifications of price fluctuations and the high priority given to agricultural product prices by governments across the world, disagreement about the drivers of price fluctuations is not merely an academic debate but one that has profound policy implications. The predicted impacts of policy interventions designed to mitigate price fluctuations hinges upon adherence to a particular theory of agricultural price fluctuations. Policies based on the first theory of price dynamics (exogenous fluctuations) discourage direct intervention in markets and instead push for the diversification of production at the farm level and maintaining appropriate aggregate levels of inventory in storage. Policies based on the second theory of price dynamics (endogenous fluctuations) endorse market interventions through planned production or production quotas in order to stabilize prices.

In light of the abovementioned debates about the theory of price fluctuations and its policy relevance in less developed countries, we examine the mechanisms behind the price dynamics in the Pakistan poultry sector, which currently generates $5 billion in annual sales, employs approximately 1.5 million people, and contributes 1.3% towards the GDP of Pakistan.

The Pakistan poultry sector is at the brink of a crisis (Government of Pakistan 2014). Many poultry farmers, particularly small and liquidity constrained farmers, have been forced to shut down their businesses due to persistent extreme fluctuations in the prices of intermediate poultry products (i.e., chicks and broilers). For instance, between 2011 and
2013, over 2500 poultry farms were shut down in Punjab (10% of total farms in Punjab), the hub of Pakistani poultry production (The Nation 2013).

Using the setting of the current Pakistani poultry sector, our paper makes several timely contributions to the applied economics literature. First, based on extensive fieldwork, we document the organization of production and the price discovery process in the poultry sector in Pakistan41. In doing so we shed light on the often poorly understood mechanics of agricultural value chains in less developed countries from a purely descriptive standpoint. Second, after taking into account the decision making practices at the level of the farm, we develop a stylized dynamic model that captures the optimizing behavior of both chick and poultry farmers within the prevalent institutional environment. We explicitly model the structural interdependencies between upstream (chick) farmers and downstream (broiler) farmers, an important aspect of agricultural production that has been overlooked in the theoretical literature on chaotic cobweb models. Third, under very general assumptions regarding cost and demand functions, we derive empirically testable hypothesis about farmers’ expectations from a derived system of coupled difference equations. Thereafter, we employ a unique, hand-collected dataset of weekly farm-gate chick and broiler prices in Pakistan from January-2008 to June-2015 to fit different time

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41These findings are based on a research project (PI: Muhammad Imran Chaudhry) funded by the Pakistan Poultry Association. This project involved detailed, structured interviews with key stakeholders in the poultry value chain during field work in Pakistan from April-2015 to October-2015. Under the supervision of the PI, a marketing research company was hired to interview approximately 50 major players in the poultry sector including grandparent stock companies, breeders, hatcheries, broiler farmers and retailers. The interview questionnaire is given in Appendix-E. The primary purpose of this exercise was to understand the organization of production and the price discovery process, in particular the structure of the poultry supply chain, information flows and the economics of decision making at the level of the farm.
series models. Our empirical analysis reveals that the behavior of poultry prices in Pakistan is broadly consistent with the theory of endogenous price fluctuations.

Lastly, we employ analytical methods and numerical tools to examine the dynamical behavior of the underlying system of time-delay difference equations derived from our theoretical model under the naïve expectations hypothesis. First, we prove existence of a unique equilibrium state. Second, we compute the system’s eigenvalues to establish asymptotic stability under the assumption of quadratic costs and linear retail demand for broilers, whereby the underlying model reduces to a system of linear time-delay difference equations. Interestingly, Hale et al. (1985) stability criterion for time delay systems independent of delays reveals that the resulting linear system is unstable independent of time-delays. Therefore in this case inclusion of time delays, usually associated with instability, actually stabilize the underlying model.

Thereafter, for the purpose of simulations, the model is calibrated with convex power functions (quadratic function being a special case of convex power functions) to represent the production costs of both types of farmers, an appropriate linear retail demand curve for broilers and reasonable values for model parameters derived from industry reports. We examine price dynamics in several interesting cases, including the special case of a linear system of time-delay difference equations and the more general case of system of nonlinear time-delay difference equations.
The simulations reveal that the model reproduces the patterns observed in Pakistani poultry prices, i.e., cyclical behavior, positive first order correlation, low skewness and negative kurtosis. Likewise, consistent with the existing literature, we document chaotic behavior in the presence of nonlinearities in the underlying system. We also implement the BDS test (Brock et al. 1987 and Brock et al. 1996) in order to characterize any chaotic dynamics in the actual price data. Although, non-chaotic behavior in the strictest sense is due to the presence of nonlinearities, interestingly, simulation results from the linear model show a markedly high sensitivity to initial conditions and model parameters. This type of behavior, at times referred to as “thin chaos”, may arise in linear time-delay models due to the intricate dynamics and complexities generated by time-delays in the feedback mechanisms.

Our findings have important ramifications vis-à-vis the literature on endogenous price fluctuations. First, we address an important gap in the theoretical literature on agricultural price dynamics. First, we find that naïve expectations can lead to complicated and even chaotic fluctuations in a vertically linked agricultural supply chain with asymmetric production lags. Second, we also bridge the gap between theory and empirics in the endogenous price fluctuations literature. Specifically, employing farmer survey responses, empirical analysis and numerical simulations and drawing on a broader understanding of the institutional environment, we make a compelling case for the existence of cobweb cycles in less developed countries.
The remainder of the paper is organized as follows. In Section 2, we describe the Pakistani poultry supply chain and present the stylized facts associated with behavior of farm-gate prices of chicks and broilers, based on extensive structured interviews of farmers, opinion surveys and market visits. In Section 3, we explain the importance of price expectations in agricultural commodity markets and summarize the literature on cobweb cycles, highlighting the key assumptions and criticisms of these models. Thereafter, we use a bounded rationality framework to argue in favor of the optimality of backward looking (naïve) expectations within the Pakistani institutional environment. In Section 4, we draw on findings presented in the previous Sections to motivate and develop a stylized dynamic model based on profit maximization by upstream (chick) and downstream (broilers) farmers in an interlinked poultry value chain. Solving the model under the naïve expectation hypothesis leads to a coupled-system of difference equations for chick and broiler prices along with related, empirically testable comparative static results.

In Section 5, we describe our empirical strategy and discuss estimates obtained from different time series models vis-à-vis cobweb cycles. In Section 6, we use analytical and numerical methods to highlight some important characteristics of the underlying dynamical system. The system of difference equations is calibrated and simulated under different scenarios in order to compare the statistical properties of the simulated data with that of observed historical data. We then employ numerical techniques commonly used in the analysis of chaotic systems to study the global behavior of orbits generated by our
theoretical model. Finally, we conclude with a discussion of the policy implications and the limitations of our underlying economic model.

2 Pakistan Poultry Sector: Organization of Production, Price Discovery & Price Dynamics

2.1 Background-Poultry Industry in Pakistan

Pakistan is the 6th most populous country in the world and is categorized as a low income agrarian economy (World Bank 2012). Agriculture is the 2nd largest sector of the economy, accounting for over 21% of GDP and providing employment to 45% of the total labor force (Pakistan economic Survey 2010). Livestock is the largest subcomponent of agriculture, contributing 11.6% towards the national GDP during 2010-12. Fueled by private sector investments and rapid mechanization, the poultry industry is the most vibrant segment of the livestock sector, with an investment of $2 billion and an annual turnover of approximately $7 billion; it generates employment for 1.5 million people (Government of Pakistan 2014). The poultry industry is also by far the most organized agricultural sector in Pakistan, with interests represented by the Pakistan Poultry Association, a non-profit business association comprising of key stakeholders in the poultry value chain.

Commercialization of poultry production began in 1964 at the behest of the federal government in major cities like Karachi, Lahore, Faisalabad, Rawalpindi, and Hyderabad. From there on the industry witnessed rapid growth primarily driven by the private sector
enterprise and facilitated by favorable government policies, including cheap credit, tax exemptions and generous subsidies on the import of breeding stock, farm equipment and poultry feed (Hussain et al. 2015). As a result, the share of traditional poultry farming (predominantly in rural areas) has steadily declined to less than 10% of chicken production over time. Production practices at modern Pakistani commercial poultry farms are increasingly consistent with global poultry industry standards. In fact, Pakistan’s breeder population is considered one of the top 10 in poultry industries worldwide (USDA 2010). To sum up, private sector involvement has fueled the rapid transition from low productivity, subsistence poultry farming to high productivity, technology intensive commercial poultry farming methods.

At the same time, due to the shortages in the supply of beef and lamb caused by the continued adherence to traditional production methods in rural areas, the share of poultry in total meat production in Pakistan has consistently increased over the past decades. According to conservative estimates, poultry products now account for between 30-40% of total meat production in Pakistan and are now relatively cheaper (substitution effect) than beef, lamb, etc. However as highlighted in table 3 below, despite the growth of the poultry sector, per capita consumption of chicken is low compared to international standards. Furthermore, with rising incomes and growth in an already large population (income effect), the demand for poultry products is expected to increase substantially over the coming decades. Therefore, from a food security perspective, continued
expansion in poultry production is critically needed to meet the rising demand for poultry products and to fulfill nutritional deficiencies among the poor.

Table 3 Production & Consumption of Poultry Chicken in Pakistan

<table>
<thead>
<tr>
<th></th>
<th>2006</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Production (KT)</td>
<td>521</td>
<td>564.3</td>
<td>575.1</td>
<td>517.7</td>
<td>539.7</td>
<td>563.7</td>
<td>589.6</td>
</tr>
<tr>
<td>Total Consumption(KT)</td>
<td>521.5</td>
<td>569.5</td>
<td>574.7</td>
<td>517.9</td>
<td>540.1</td>
<td>564.4</td>
<td>590.7</td>
</tr>
<tr>
<td>Per Capita Consumption(Kg)</td>
<td>3.1</td>
<td>3.3</td>
<td>3.2</td>
<td>2.9</td>
<td>2.9</td>
<td>3.0</td>
<td>3.1</td>
</tr>
</tbody>
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It is interesting to note that, unlike developed countries, due to the lack of cold storage facilities and consumer preference for fresh chicken\(^{42}\), the Pakistani poultry sector is primarily a live bird, rather than chilled/frozen bird market. Consequently, international trade in poultry products (chicks and broilers) plays a negligible role in Pakistan as evidenced by the relatively equal levels of production and consumption in table 3. At the same time, export of chicken to adjacent India, Iran and Afghanistan is officially banned. These observations have important ramifications vis-à-vis price volatility, because in the absence of inventory and international trade, even small changes in supply can result in large price fluctuations. We take these features of the poultry sector into account in the formulation of our theoretical model in Section 3.

\(^{42}\) A primary driver of preferences for freshly slaughtered chicken is a high concern about the halal status of chicken among consumers in Pakistan, a predominantly Muslim country.
2.2 Key Features of the Pakistani Poultry Value Chain

Despite gains in production efficiency, the organizational structure of the Pakistani poultry sector poses several challenges to sustained growth in poultry production. First, unlike poultry farming in the US, the poultry sector in Pakistan is neither vertically integrated nor characterized by contract farming agreements. Second, in contrast to the pervasiveness of integrators\textsuperscript{43} in developed countries, the value chain in Pakistan consists of relatively small number of firms operating independently, often based on shortsighted goals. Third, institutional voids and an opaque information environment further convolute production decisions at the farm level. We discuss each of the aforementioned factors in the following paragraphs.

The key players the Pakistani poultry supply chain can be categorized into: grandparent stock companies, parent stock companies/breeders, hatcheries and broiler farmers. Grandparent stock companies import broiler stock and rear it to produce parent stock or broiler breeders\textsuperscript{44}. However, as is often the case in developing countries, artificial scarcity created by trade quotas makes import licenses valuable and a source of monopoly rents. Consequently licenses are contested through political connections and kickbacks (Krueger 1974). Likewise, in Pakistan, in 2008 only two companies imported grandparent stock at an unofficial fixed price of Rs. 250/bird. In 2014, this number increased to four, causing the price of parent stock to decline to Rs. 150 per bird. Parent

\textsuperscript{43}Integrators are firms that have expanded their operations to span the entire poultry value chain, i.e., beginning with acquisition of parent stock, to raising parent stock and chicks, to rearing broilers and even selling to consumers.

\textsuperscript{44}Famous brands of Grand Parent stock being imported in Pakistan include Hubbard and Ross.
stock chicks purchased from grandparent stock companies are reared to produce fertilized eggs by the breeders. Thereafter, the fertilized eggs are sold to hatcheries and incubated in order to produce day-old chicks. The hatcheries sell the day-old chicks to broiler farmers, who grow them into broilers that are eventually sold to retailers via commissioned agents.45

Geographically, production is concentrated in the northern part of Pakistan, in particular Punjab, the most populous and economically productive province of Pakistan. The southern part of Pakistan, in particular Karachi and adjoining areas represent the other production belt. The poultry sector in northern Punjab accounts for approximately 70% of the total national production and is relatively more capital intensive, due to the relatively higher percentage of control sheds compared to the poultry farms in the southern part of Pakistan. Apart from a limited degree of integration among breeders and hatcheries, the value chain is fragmented and spanned by thousands of independent poultry farms. According to PPA (2015), there are more than 25,000 poultry farms spread over the two production belts, while estimates of production show parent stock placement of 11 million along with chick and broiler production of 1.1 billion and 1.05 billion, respectively.

45The focus of this paper is gaining an understanding of the underlying causes behind the price fluctuations in the farm-gate prices of day old chicks and broilers, i.e., the production value chain as opposed to price transmission from the farm sector to the retail sector. Therefore, we digress from a detailed description of the marketing channel. Nevertheless, very briefly, based on fieldwork in Pakistan we found that unlike the marketing channel in the developed countries which is dominated by large retailers and processors, the retailers don’t enjoy any market power in Pakistan. In fact, retailers comprise of small setups scattered around towns, which primarily slaughter live chicken for consumers on demand and possess little bargaining power vis-à-vis poultry farmers, empirical estimates from standard price transmission models support these observations.
Despite the relatively large size of the poultry sector, there is a lack of coordination of production decisions at different stages of the poultry value chain. Moreover, there is no timely source of official publicly available data on key variables such as parent stock placement by breeders or production at hatcheries at the association level or regionally. Decision making at the farm level across the value chain is further complicated by the absence of futures exchanges for poultry products, particularly broilers. The weak institutional environment and poor contract enforcement implies that production cannot be pre-contracted. Since contracts carry little value in situations of adverse price movements (e.g. if market price of chicks falls below the contracted chick price), many broiler farmers renege on their contracts with hatcheries. To make matters worse, an underdeveloped marketing channel means that farmers cannot preempt changes in demand and adjust production based on pre-order information received from retailers. We reiterate these issues in the subsection on Pakistani poultry farm economics below.

To summarize, the price of parent stock is fixed due to the monopoly rents generated by import licenses held by grandparent stock companies. Nevertheless, the relatively large number of chick and broiler farmers diminishes any market power concerns further downstream. Even though production is concentrated in northern Punjab, the poultry sector is not vertically integrated despite the fact that the production of chicken involves various intermediate and closely interlinked production processes. We now turn our attention towards the mechanical aspects of the broiler chicken production cycle.

46Based on data provided by PPA, the eight firm-concentration ratio is approximately 50% and 10%, respectively in the hatchery and broiler subsector of poultry value chain.
2.3 *Mechanics of the Production Cycle*

Compared to other agricultural commodities, i.e., crops and livestock, a unique feature of the poultry value chain is its relatively short production cycle, which is most appropriately measured in weeks compared to months and or years. Moreover, in the absence of vertical integration or contract farming, another interesting feature of the poultry production cycle arises from the interdependencies between upstream and downstream farmers created by the interlinked and sequential nature of the production process. Therefore, unlike the previous theoretical literature on cobweb models, one cannot merely focus on price fluctuations in the final downstream product whilst ignoring the price dynamics in the upstream product. We specifically model these interdependencies in our paper; for further details please refer to Section 4 below.

In the first stage, breeders purchase the parent stock from the grandparent stock companies at a predetermined, fixed price. After an unproductive rearing period of 25 weeks, the parent stock enters production for approximately 66 weeks and produces on average 120 fertilized eggs over its life cycle. However, productivity declines after an initial surge, and if chick prices are low, the parent stock is sometimes strategically culled and sold on the broiler market before the end of its productive life to take advantage of high broiler prices. Based on feedback received from poultry farmers in Pakistan, the average productive period of parent stock is around 60 weeks. Breeders in Pakistan maintain parent stock at different stages of the lifecycle at any given time to smooth cash

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47 There is no domestic production of the grandparent stock and it is simply imported from abroad, therefore we begin the description of the production cycle from the parent stock.
flows and on average buy new parent stock chicks thrice a year. Fertilized eggs produced by the parent stock technically can be sold in the table egg market, although this rarely happens in practice due to price considerations.

The hatcheries purchase fertilized eggs from breeders and incubate the fertilized eggs in controlled environment sheds for exactly 3 weeks. Unlike breeders, hatcheries, at any given time possess a single batch of fertilized eggs, all of the same age. Although some farmers have multiple sheds and purchase fertilized eggs continuously, fertilized eggs for a given hatchery are purchased on a 3-week cycle. The eggs hatch on the 22nd day and the resultant chicks must be sold as soon as possible in order to maintain cash flows and prepare the shed for the incubation of a new batch of fertilized eggs. According to chick farmers, after the 22nd day, chick mortality increases drastically with time; therefore they are in a rush to sell the chicks to broiler farmers.

Broiler farmers’ purchase the chicks directly from the hatcheries\(^{48}\). The chicks are grown into broilers and reach market weight in approximately 6-7 weeks depending on the type of shed, quality of feed and the season. Like hatcheries, broilers at a given broiler farm are, at any point in time, all of the same age and are sold to retailers via commission agents as soon as they reach market weight, because the ratio of feed-cost to weight-gain and the mortality rate increases significantly after this weight. Since the market for

\(^{48}\)There is no intermediary between the chick farmers and broiler farmers in the Northern production belt, while in southern production belt commission agents act as an intermediary between hatcheries and broiler farmers. As mentioned later, our price dataset concerns the northern production belt, therefore we make the above statement.
poultry chicken in Pakistan is primarily a live bird market, broiler farmers are forced to sell broilers at the prevalent market rate. Thereafter, broiler farmers buy the next batch of chicks and the cycle continues. Figure 8 summarizes the production linkages of the poultry value chain.

Figure 8 Poultry Production Cycle

2.4 Price Discovery Process

The price discovery process deals with issues related to the “mechanics” of pricing. In particular, it describes the institutional arrangements, information flows and methods employed by buyers and sellers to arrive at transaction prices (Tomek & Robinson 2003). Unsurprisingly, price discovery process depends on the economic settings, institutional environment, technical advancements and transactions costs. We describe these factors along with their impact on price discovery in the following paragraphs.

The chicken market in Pakistan is primarily a live bird market with approximately 98% of the demand for chicken met by freshly slaughtered broilers, with approximately 5
million broilers slaughtered daily (Haq 2014). Therefore, markets for intermediate poultry products, especially the chick and broiler markets are very active. In the absence of cold storage facilities, vertical integration or pre-contracted production, the current supply and demand fully determines the market clearing price for both chicks and broilers. The impact of current supply on market prices is further amplified by the fact that both chicks and broilers are highly perishable products and must be sold off as soon as “ready”, often on the same day. Consequently, poultry farmers have to sell their production at the prevailing market price and cannot “hold” supply in anticipation of more favorable prices in the future. Therefore, as opposed to short-run, very short-run supply determines equilibrium prices. At the same time because of the interlinked nature of the production process, the supply of chicks and broilers is mutually interdependent; therefore, chick prices are affected by broiler prices and vice versa.

The government plays a minimal role in the price determination processes in poultry markets in Pakistan. Prices adjust to ensure that markets clear instantaneously in both the broiler and chick markets. Market clearing farm-gate prices for both chicks and broilers are published daily by the Pakistan Poultry Association (PPA). These prices are finalized after reviewing the going rate at poultry auction markets known as Mandis in northern Punjab and consulting large hatcheries and broiler farmers active in the chick/broiler markets on a given day. The Mandis serve as congregation points for potential buyers and sellers of chicks and broilers from different locations across Pakistan. The availability of good road networks in the production hub of northern Punjab facilitates the participation
of large number of buyers and sellers from different adjoining areas. The continuous interaction between buyers and sellers leads to rapid aggregation of information on demand and supply into prices, leading to the determination of equilibrium, market clearing prices.

The PPA rate serves as the reference rate for the transactions between both chick and broiler farmers and broiler farmers and retailers across Pakistan. Given the relatively short poultry production cycle, information regarding prevailing prices spreads quickly due to significant improvements and expansion in the information and communications infrastructure (ICT) in Pakistan over the last decade. Additionally, due to the improvements in the road and transportation network, many arbitrageurs seek to exploit regional price differentials. Consequently, large regional price differentials net of transportation cost are quickly arbitraged away. Although negotiations and bargaining on the transaction price takes place between counter parties based on payment terms and sometimes even product quality, the highly competitive nature of poultry sector ensures that major deviations from official PPA prices are uncommon.

In summary, broiler and chick prices are, by and large, determined by the current (or very short-run) supply and demand situations. Mandis, arbitrageurs, good road networks and widespread use of ICTs facilitate the aggregation of demand/supply information into prices and leads to rapid price adjustments across different regions engaged in poultry production. Therefore, the market clearing price documented and disseminated by the
Pakistan Poultry Association is representative of price levels at which broilers and chicks are bought and sold in Pakistan, and thus reflective of overall demand and supply.

2.5 *Price Data-Stylized Facts*

We now highlight the stylized facts associated with the prices of broilers and chicks. Price data provided by Pakistan Poultry Association and comprises daily, market clearing farm-gate prices for chicks and broilers in Punjab (PPA-North Region), the production hub of poultry and the most populous province of Pakistan, from June 2008 to June 2015. According to Pakistan Poultry Association, these prices are representative of prices in other parts of Pakistan and are used by the Federal government in computation of price levels (CPI, inflation etc.). Given that the poultry production cycle is most aptly measured in weeks, we converted daily prices into average weekly prices for the sake of consistent estimation and intuitive interpretation⁴⁹. Summary statistics are shown in table 4.

<table>
<thead>
<tr>
<th></th>
<th>Max</th>
<th>Min</th>
<th>Mean</th>
<th>Std-Deviation</th>
<th>Coefficient of Variation</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Broiler</strong></td>
<td>173.29</td>
<td>58.00</td>
<td>110.37</td>
<td>23.14</td>
<td>0.21</td>
<td>0.21</td>
<td>-0.48</td>
</tr>
<tr>
<td><strong>Chicks</strong></td>
<td>74.00</td>
<td>4.29</td>
<td>36.29</td>
<td>16.36</td>
<td>0.45</td>
<td>0.26</td>
<td>-0.65</td>
</tr>
</tbody>
</table>

Table 4 Summary Statistics for Broiler & Chick Prices

The summary statistics are based on average weekly prices from June 2008 to June 2015. The data was sourced from Pakistan Poultry Association (North). All prices are in nominal units of the local currency.

⁴⁹Section 4 provides several reasons for converting daily prices into weekly prices.
Table 4 highlights the variation in both price series. The difference between weekly minimum and maximum prices for broilers and chicks is particularly noteworthy. Using the coefficient of variation to normalize average price variability (measured by the standard deviation), we find that on average the variability in chicks prices is approximately twice that of broiler prices. Both price series depict low skewness and negative kurtosis, compared to the positive kurtosis displayed by most agricultural commodities. Taken together, these observations imply that both price series are characterized by a relatively flat probability distribution, i.e., fatter tails (frequent peaks and troughs).

The relatively long coverage of the dataset (8 years) allows us to observe the dynamics of price fluctuations. Figure 9 shows the evolution of broiler prices and chick prices over time with (nominal) price in Pakistan Rupees on the vertical axis. The solid lines show a simple time trend of each price series, whereas the dotted black line denotes a six-week moving average.

First, and foremost, we note that there has been dramatic variation in poultry product prices that show no sign of dampening; in fact fluctuations have actually increased over time. A simple linear trend line, drawn for each price series reveals that broiler prices on average have risen over time, but chick prices have remained largely stagnant. Second,

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50As the forthcoming analysis will show, the broiler prices play a fundamental role in the production decisions of both chick and broiler farmers. Therefore we used 6-week moving averages, the approximate length of the broiler production cycle, to analyze the variability in broiler and chick prices.
both series show very strong cyclical behavior, i.e., prices repeatedly rise and fall in cycles, often multiple times in a given year. However, the “amplitude” and “frequency” of these cycles is not constant and changes over time. These cycles cannot be explained by seasonal dummies based on the Gregorian calendar. This is intuitive, since chick and broilers are continuously produced throughout the year, whilst demand for chicken is fairly stable within a certain price range.

Figure 9 Time Series Line Plots of Broiler & Chick Prices

In the empirical literature price cycles driven by seasonality are usually assumed to be deterministic and thus relatively easy to identify based on the Gregorian calendar within a simple regression framework. In our case, monthly dummies based on the Gregorian calendar could not explain the cyclical behavior. Other types of seasonality are discussed in Section 4.
The dotted lines, representing the 6-week moving average, lend support to the abovementioned observations and reveal a systematic component to the cyclical behavior. In a nutshell, both prices series are characterized by dramatic variability and cyclical behavior that, as we will argue later, cannot be explained by fundamentals and may be a manifestation of chaotic cobweb cycles.

3 Cobweb Models: Key Assumptions, Criticisms & Refinements

3.1 Cyclical Behavior of Agricultural Product Prices

In theory, a price cycle is defined as a price pattern that repeats itself over time with a fixed period and amplitude. But this idealistic definition of cyclical behavior seldom holds in reality due to the interaction of several systematic components in agricultural product prices, e.g., seasonality, random shocks and deterministic time trends. As a result, the period and amplitude of price cycles in agricultural commodities usually varies from one cycle to another due to the presence of the abovementioned systematic components. Therefore, exact empirical identification of cycles, i.e., isolating the stage that a cycle is in at any given time, is almost impossible in practice. Nevertheless, price cycles in agricultural commodities usually depict (qualitatively) repetitive behavior which is characterized by periods of rising prices followed by periods of declining prices and vice versa.

The literature has provided two major explanations to explain the underlying causes behind cyclical behavior of prices and the associated price volatility. The theory of
exogenous price fluctuations originally developed by Muth (1961) and vastly improved upon by later researchers (Deaton & Laroque 1992, Deaton & Laroque 1996, Chambers & Bailey 1996, Osborne 2004 and Williams & Wright 2005) is based upon different models of competitive storage under the rational expectation hypothesis. According to this theory, random shocks like droughts and epidemics lead to a temporary reduction in supply and hence high prices, whilst good weather shocks and low incidence of diseases may lead to a supply glut and hence low prices. However, given that such shocks are rare, price cycles caused by external shocks dampen over time as production returns to normal levels and prices converge to levels consistent with long run equilibrium in the absence of new shocks. Similarly, price cycles may be driven by seasonality of production (Miranda & Glauber 1993b and Lowry et al. 1987). For example, the production of certain crops is tied to particular seasons, i.e., periodic production and prices gradually increase after the end of the production season due to lack of new supplies entering the market.

Gouel (2012) provides a detailed review of the price dynamics and key features of different versions of the competitive storage model employed in agricultural economics literature. Consistent with the rational expectation hypothesis, farmers are assumed to possess complete albeit imperfect knowledge of the underlying structure of the aggregate supply and demand equations along with the relevant information on variables related to prices in these models. Although uncertain about the actual realization of prices, farmers know the probability distribution of future prices and hence the mean price. Therefore, price cycles are a short term phenomena and represent deviations from the long run
equilibrium level due to the incidence of external shocks or seasonality of production and not any systematic changes in the production decisions of farmers. However, the stylized facts associated with real world price data, in particular large first-order autocorrelations, positive skewness and kurtosis cannot be easily replicated by price fluctuations generated from models of competitive storage.

In fact, in the absence of storage, price data generated from these type of models is characterized by unrealistically low first order correlation and large negative skewness. This is noteworthy, because poultry products are not storable at all the stages of production in our institutional environment. Thus, even though the competitive storage model is appropriate for seasonally produced storable commodities (grain etc.), it is clearly not very relevant to continuously produced nonstorable commodities (poultry etc.). This brings us to another theory of price cyclicality, i.e., endogenous fluctuations.

### 3.2 The Cobweb Model Underlying Phenomena & Key Assumptions

The cobweb model is a popular conceptual framework to explain persistent cyclical movements in the prices of agricultural products. The original model, due to the seminal work of Ezekiel (1938), challenged the notion in neoclassical economics that production/prices converge to equilibrium following random shocks and instead showed that systematic forecast errors can lead to periods of over and undersupply, resulting in cyclical price fluctuations. However due to its simplistic nature, the original cobweb model was merely a pedagogic tool with limited applicability to real agricultural markets,
although later work by Nerlove (1958) addressed some of the early criticisms directed at the original cobweb model. Nonetheless, despite not being the mainstream approach, simple cobweb models symbolized an alternative view of price fluctuations, i.e., theory of endogenous price fluctuations till the early 1990s. However, recent advancements in the analysis of chaotic systems and the emergence of chaos theory has resuscitated interest of economists in cobweb models of commodity prices (Mitra & Boussard 2012, Westerhoff & Wieland 2010, Schenk-Hoppé 2004 and Lundberg et al. 2015). We put off a discussion of this stream of literature for now, in order to first lay out the essential features of a simple cobweb model.

In a simple cobweb model, quantities and prices are determined sequentially in a linked causal chain due to the time lags between the decision to produce and realization of actual production plans. The underlying phenomenon is intuitive: farmers increase (decrease) planned future production in view of high (low) current prices under the presumption that high (low) prices today will translate into high (low) prices in the next period. This results in a supply glut (shortage) when planned production is realized in the next period, leading to low (high) prices. Therefore, simple cobweb models generate periodic oscillations of high and low prices, resulting in negatively auto-correlated prices.

Like all models, the cobweb model of price fluctuations relies on some key assumptions. First, a time lag must exist between the decision to produce and the realization of actual production. Evidently, in the case of agricultural commodities, this assumption almost
always holds in reality due to the biological nature of the production process. Second, producers are price takers in the output market and current prices are primarily determined by the realization of current production, i.e., absence of inventories and trade in the given agricultural commodity. Though true in our specific institutional environment, this assumption may not hold in other agricultural commodities like grains that can be easily stored and imported/exported. Lastly and most controversially, producers in cobweb models are assumed to base their production decisions on current prices (naïve expectations) or a weighted average of current and past prices (adaptive or quasi-naïve expectations). In other words, producers use information embedded in today’s prices to forecast future prices in a cobweb model or put more simply producers simply expect current (or recent past) prices to continue in the next period (extrapolative or backward looking expectations).

Many have criticized the assumption of naïve expectations or backward looking expectations in cobweb models. The standard argument is that farmers can adopt counter cyclical strategies, i.e., plan to produce less (more) when current prices are high (low). In doing so they not only earn superior profits but their counter cyclical production strategies will also dampen the price cycles. But the issue is not as simple as it seems, because the development and evolution of price cycles is difficult to predict ex-ante due to the interactions between different systematic components in agricultural prices, i.e., seasonality, time trends and random shocks (Tomek & Robinson 2003). Moreover, as argued above, the period and amplitude of price cycles changes over time in response to
interaction of many factors. Therefore, though straightforward in theory, successful adoption of countercyclical strategies is not easy in practice due to inadequate knowledge about future trajectories of price cycles. Moreover, if the price series depicts chaotic behavior, then adopting a simple countercyclical strategy does not guarantee superior profits due to the inherent randomness in prices, especially in our settings, where production cannot be stored and has to be sold at the prevailing market rate.

3.3 Importance of Expectation Regimes in Agricultural Economics

The specification of an expectation regime is a key ingredient of dynamic models in neoclassical economics\textsuperscript{52}, and even more so in agricultural economics due to the time lag between production decisions and actual realization of agricultural output. Consequently, expectations (i.e., forecasts of future output prices) play a key role in the production decisions of farmers and as a result much of the analysis pertaining to the supply of agricultural commodities revolves around future (output) price expectations of farmers (Sulewski et al. 1994). Of course, there is a direct link between producers’ formulation of expectations and the dynamics of agricultural product prices (volatility, cyclicality etc.). If production decisions in the current period depend on the expectations of output prices in the next period, then expectations of future output prices today will have a large impact on the future realization of actual prices (assuming minimal effect of inventories and trade).

\textsuperscript{52}The theoretical foundations of modern macroeconomics, developed by renowned economists like Lucas, Sargent & Barro in the 1980s, draws heavily on the rational expectations hypothesis proposed by Muth (1961).
Given the significance of expectations in economic models, unsurprisingly, one finds disagreements among economists regarding the “correct” formulation of expectation regimes. However, since expectations about future prices cannot be directly observed in the absence of efficient futures markets, there is no easy resolution to this debate. Nonetheless, the unobservability of expectations has not hindered economists from employing several different methodologies including econometric techniques, direct surveys and laboratory experiments to empirically test hypothesis related to the different expectation regimes, e.g., rational expectations, quasi-rational expectations, adaptive expectations or naïve expectations. Before reviewing the empirical literature on expectations, we briefly highlight the key features and implicit assumptions of the rational expectation hypothesis.

3.4 Rational Expectation Hypothesis-Key Features, Implicit Assumptions & Empirical Tests

Few would doubt that the rational expectation hypothesis, originally formulated by Muth (1961), is the dominant approach in the economics literature to formulate expectations. However, the popularity of the rational expectation hypothesis does not stem from an accumulated body of empirical evidence but instead is based on a logical structure that allows economists to formulate and solve economic models (Lovell 1986). Nevertheless, the emergence of the bounded rationality framework has increasingly challenged the dominance of the rational expectation hypothesis, especially in the aftermath of the recent financial crisis.
According to Muth (1961), expectations that are consistent with the underlying economic model are rational, i.e., the subjective expectation of economic agents equals the mathematical expectation in the underlying economic model conditional on the available information. However, as many economists have pointed out, the requirements of the abovementioned consistency requires stringent and often unrealistic assumptions. First, agents have perfect knowledge of the structure of the model and equilibrium relationships derived from the underlying model are used to forecast endogenous variables. Second, acquisition and processing of information is costless. Whilst the information set of agents contains information on all available variables that are thought to influence future prices, including endogenous variables, exogenous processes (the probability distribution of random shock) and expectation of other agents etc. (Irwin & Thraen 1994). A corollary of this representational scheme is that agents know the probability distribution of future prices (hence the mean price) even though the actual realization of future prices is unknown. Consequently, forecasts of agents in a rational expectations equilibrium converge towards actual realizations in expectation.

From the implementation standpoint, apart from the computational difficulties, the validity or “rationality” of prices derived from the rational expectation equilibrium requires that the underlying economic model is correctly specified vis-à-vis the information set of agents, i.e., variables included in the demand and supply equations (Irwin & Thraen 1994). Therefore, predictions from rational expectation models are sensitive to the underlying structure of economic models and any empirical test of the
rational expectation hypothesis is also a joint test of the underlying model (the joint hypothesis problem). Consequently, many researchers simply employ a futures market quote (assuming futures markets are efficient and aggregate all relevant information) to operationalize the rational expectations hypothesis in empirical research or use forecasts from an econometric model (quasi-rational expectations).

Although firmly embedded within the tradition of neoclassical economics, the rational expectation hypothesis has little empirical support. Empirical work on expectations can be divided into two broad categories, i.e., indirect tests based on structural econometric models and direct tests based on (model free) survey results. Irwin & Thraen (1994) present a detailed review of empirical tests of rational expectation hypothesis in agricultural economics and find that tests based on econometric models fail to offer any consensus regarding the verification or falsification of the rational expectation hypothesis, despite spanning an array of agricultural commodities and different time periods.

For example, Shonkwiler & Emerson (1982) find that expectations of farmers in the US tomato sector are consistent with rational expectations but Shonkwiler & Spreen (1982) find that expectations of farmers in the US lettuce market are consistent with naïve expectations. Likewise, while Goodwin & Sheffrin (1982) make a strong case for rational

53 “Model free” means that a survey measure of expectations is independent of an econometrician's specification of the market's structure. This characteristic of survey expectations is attractive, and leads some economists to argue that direct tests of rationality are superior to tests based on structural econometric models” Irwin & Thraen 1994 pg.
expectations in the US broiler industry, while Antonovitz & Green (1990) reject the rational expectation hypothesis in the US beef cattle market. According to Irwin & Thraen (1994) the variability in the results of empirical tests of the rational expectation hypothesis is driven by the low power of statistical tests and specification searching by researchers.

More recent work presents a similar picture. For instance, Chavas (1999a) estimates a dynamic structural model of profit maximization by farmers in the US poultry sector and finds that expectations of approximately 90% of poultry farmers are consistent with backward looking expectations. Based on a similar approach, Chavas (1999b& 2000) find that a large proportion of US beef and pork producers’, respectively behave naively, i.e., base future production decisions only on the most recently observed market prices, while a significant minority conforms to quasi-rational expectations. Our paper also contributes towards this stream of empirical literature, i.e., empirical test of farmers’ expectation regimes based on a structural economic model.

However, direct tests of expectations, i.e., empirical analysis of survey data (checking for unbiasedness and orthogonality of forecasts), reveals a less ambiguous picture of expectation formation. Based on analysis of micro survey data on exchange rate expectations of financial institutions, Ito (1990) rejects the rational expectation hypothesis but finds significant heterogeneity within the expectations regimes of different agents. Kawasaki and Zimmermann (1986) arrive at similar conclusions, using survey
data from manufacturing firms about future demand forecasts. After reviewing several empirical studies based on surveys pertaining to expectation formation, Lovell (1986) concludes “….it seems to me that the weight of empirical evidence is sufficiently strong to compel us to suspend belief in the hypothesis of rational expectations, pending the accumulation of additional empirical evidence.”

This view is mirrored in the agricultural economics literature as well. Irwin & Thraen (1994) conclude that the overall results of survey studies favor rejection of the rational expectation hypothesis. For example Beach et al. (1995) find that expectations of vegetable farmers are inconsistent with the rational expectation hypothesis. Likewise, Runkle (1991) finds that hog farmers breeding decisions are not rational; similarly Irwin et al. (1992) reject the rational expectations hypothesis after analyzing the expectations of hog and cattle farmers in the US.

The burgeoning behavioral and experimental economics literature echoes a similar view. For example, Heemeeijer et al., (2009) finds that that subjects prefer to use simple rules of thumb that are inconsistent with the rational expectation hypothesis to forecast future prices. Hey (1994) finds that though subjects “try to” behave rationally, but their expectations bear a clear resemblance to backward looking expectation regimes. The abovementioned findings are consistent with anecdotal evidence, which suggests that farmers normally use the most recently received price to predict prices in the next period as opposed to forecasts from complicated models.
3.5 Naïve Expectations or Rational Expectations—Towards a Resolution

Given the fairly strong assumptions of the rational expectation hypothesis, it is not surprising to find a lack of empirical support for the rational expectation hypothesis. Undoubtedly the rational expectations hypothesis has a certain appeal that draws from its logical structure and internal consistency, which allows economists to build elegant models and derive strong analytical results. However, the assumptions of the rational expectation hypothesis, i.e., perfect knowledge of the underlying structure of the data generating process and costless acquisition/processing of available information simply do not hold in reality. Perfect knowledge of an underlying model that is essentially unobservable overestimates the processing ability of economic agents. For example, the experimental economics literature has clearly shown that agents prefer simple rules of thumbs to forecast prices as opposed to complicated models. This is even more likely in the case of the largely uneducated farmers in less developed countries, unfamiliar with basic concepts of mathematical modeling and statistical forecasting. More importantly, often accurate information on stocks, inventories and competitors production plans is simply not available, especially in less developed countries.

Second, as argued by Grossman and Stiglitz (1976), if the costs of acquiring and processing information exceed the perceived benefits of better forecasts, then even rational actors will choose not to employ all the available information to forecast future variables. An alternative and more realistic view, the bounded rationality framework argues that economic agents possess limited information processing ability and thus
weight the costs and benefits of acquiring additional information whilst formulating expectations about future outcomes. This is in contrast to models based on rational expectations (Miranda & Helmberger 1988), where only the benefits of additional information vis-à-vis expectations are considered whilst ignoring the cost of collecting and processing information. Interestingly, in their seminal work, Brock and Hommes (1997) show that forecasts based on naïve expectations can be both rational and optimal if acquisition and processing of information is costly. Moreover, they show that several expectations regimes are potentially rational in an environment where agents have heterogeneous information processing costs.\(^\text{54}\) We further elaborate these points in Section 4.1.

In summary, in light of the empirical literature on expectations and anecdotal evidence derived from fieldwork and surveys in Pakistan, the assumption of naïve expectations does not seem unrealistic or “irrational”. In fact, the suitability of a given expectation regime hinges upon the specific institutional environment and background of the underlying research problem. Therefore, a solid understanding of the context of the research problem is essential to correctly specify an appropriate expectation regime. This understanding should help researchers’ answer the fundamental question: What types of information are commonly available to farmers at the time of making production decisions? Few would argue with the fact that current prices are the only source of

\(^{54}\)As mentioned above, industry studies also indicate that commodity producers have heterogeneous price expectations. This is not surprising given that different producers possess different information and have different costs associated with information collection and processing (Burton & Love 1996). However, we do not explicitly account for this aspect in our paper.
reliable information easily available to poultry farmers in less developed countries plagued by numerous institutional voids and information asymmetries. Additionally, low levels of human capital (poor literacy rates compounded by limited opportunities of quality education) mean that prices also represent a category of information that is relatively “cheaper” to process, compared to information on stock levels, aggregate production and demand. In short, while, rational expectations hypothesis may be valid in certain economic environments, it does not seem to be a viable assumption in our settings. We reiterate features of the economic environment that lend support to the assumption of naïve expectations in the poultry sector in Pakistan in Section 4

3.5 Price Dynamics in Chaotic Cobweb Models

As mentioned before, price dynamics in the original cobweb model are limited to three simple but unrealistic cases, i.e., explosive divergence, periodic cycles and convergence to a steady state. Explosive divergence, leading to negative prices is obviously not feasible. Deterministic cycles with fixed periods can be exploited by farmers pursuing counter-cyclical production plans, which will lead to dampening of the price cycles. Convergence to a steady state, though consistent with the neoclassical economic theory, contradicts the actual poultry price data, which is best characterized by quasi-cyclical behavior.

However, researchers have developed several refinements of the original cobweb models over the past decades that depict price dynamics consistent with real world data. This
stream of literature, popularly known as chaotic cobweb cycles, introduces non-linearities into the supply/demand equations whilst keeping the essential features of the original cobweb model, i.e., backward looking expectations and production lags. Analogous to real world prices, price dynamics generated from chaotic cobweb models depict seemingly random behavior, even though the models are entirely deterministic. Another interesting feature of chaotic cobweb models is their sensitivity to initial conditions, whereby small perturbations to parameters or initial values results in qualitatively different price trajectories. However, data generated by chaotic cobweb models show low first order autocorrelations and negative skewness, in contrast to high first-order autocorrelation and positive skewness (occasional spikes) in the real price data.

Researchers have proposed several explanations for the differences between data simulated from chaotic cobweb models and actual prices, including slow adjustment towards optimal production in response to changes in prices (Onozaki et al. 2000), heterogeneous expectations (Chavas 1999a and Chavas 2000), risk aversion (Boussard 1996) and storage (Mitra & Boussard 2012). Several other factors, like prices of substitutes and complements, consumer preferences, institutional factors like tariffs and production technology, also have a nontrivial impact on the cyclical behavior of actual prices of agricultural products. For example, Westerhoff and Wieland (2010) develop a cobweb commodity model that accounts for interaction among consumers, producers and heterogeneous speculators, and which reproduces price dynamics that mimic the cyclical price movements in actual commodity markets. Similar to our approach, Dieci and
Westerhoff (2012), set up a model with two interacting linear cobweb markets, whereby farmers choose to produce either good based on profit differentials between the markets in any given period. Non-linearities in their model are endogenously generated by allowing suppliers to “switch” between markets. They find that interacting cobweb markets contribute to the price cyclicality observed in real world data. Lundberg et al. (2015) arrive at similar conclusions in a model of interacting cobweb markets with land-use competition between food and bioenergy crops.

Though, horizontal linkages between agricultural markets have been studied in the burgeoning theoretical literature on cobweb models, mutual interdependencies between upstream farmers and downstream farmers, an important aspect of agricultural production, have been largely overlooked. In addition to the empirical contribution, we address this gap in the theoretical literature by developing a simple model to capture the vertical linkages between upstream and downstream farmers in agricultural value chains under the naïve expectation hypothesis. Although specific to the poultry industry, our model can be modified to analyze other vertically-linked cobweb markets, especially livestock markets. An interesting feature of the vertically linked agricultural value chains is the interdependency between upstream and downstream farmers, which imply that that prices of upstream products are a function of expected prices of both downstream and upstream products. Also, in contrast to the theoretical literature on horizontally linked agricultural markets, our model has asymmetric production lags (also known as a time delay system) due to the differences in the length of production cycles of upstream
(chicks) and downstream farmers (broilers). The details of the model are provided in the next Section.

To summarize, in this Section we have briefly reviewed the theoretical literature on price fluctuations in agricultural market. Thereafter, in light of the relevant empirical literature on the formation of expectations, we argued that the observed fluctuations in prices of poultry products in Pakistan are a manifestation of cobweb cycles. Lastly, we highlighted important features of chaotic cobweb markets and important contributions in this area. In the next Section we formulate a stylized dynamic model to simultaneously capture the optimizing behavior of chick and poultry farmers within the prevalent institutional environment under the naïve expectation hypothesis.

4 Theoretical Framework: Endogenous Price Fluctuations in an Interlinked Agricultural Market

Armed with an understanding of the institutional environment, the mechanics of the production cycle and the price discovery process in the poultry sector in Pakistan, along with an overview of the broader literature on cobweb cycles, we turn our attention toward the production decisions of poultry farmers at the farm level.

4.1 Poultry Farm Economics—Some Key Observations from Farmer Surveys

Based on fieldwork in Pakistan (see Appendix-E for details of fieldwork), we found that the price of parent stock does not play a significant role in the short-term production
decisions of farmers in the poultry value chain for several reasons. First, for reasons described above, breeders are generally cash rich companies with market power and hence produce at optimal capacity regardless of market prices in the short run. Accordingly, the price of parent stock remained fixed at Rs. 250/unit between 2008 and 2014, and decreased to Rs. 150/unit afterwards due to entry of additional grandparent stock companies. Second, as described in Section 1, the lifecycle of parent stock is approximately 100 weeks, compared to 3 weeks and 6-7 weeks for chicks and broilers, respectively. Therefore unlike hatcheries and broiler farmers, breeders or parent stock farmers cannot adjust production levels over short intervals in response to price signals. Therefore, one can conclude that the observed short-run price fluctuations do not stem from the decisions of parent stock farmers since the price of parent stock is fixed during and parent stock production is fairly stable. However, parent stock placement is not important in explaining short run price dynamics, we acknowledge that it has an impact on poultry prices in the long run. Moreover, on average, the cost of parent stock procurement represents approximately 5% of the total production cost of breeders. Therefore, we believe that overlooking parent stock dynamics in our theoretical model does not impact the validity of our conclusions.

Feed costs, which comprise approximately 60% of the total production costs, are a major component of production expenditures incurred by breeders and broiler farmers\textsuperscript{55}. For

\textsuperscript{55} More specifically, for breeders variable costs comprise of feed (60%), parent stock price (5%), vaccinations and medicine (10%), while fixed costs (25%) include rent of controlled sheds, overheads and wages (5%). In the case of broiler farms, variable cost comprises of chick price (30%) and feed (60%), while fixed costs (10%) include rent of controlled sheds, overheads and wages.
broiler farmers, production costs are driven primarily by the rearing expenses incurred on chicks and hence tied to the number of chicks procured at the beginning of the production cycle, whereas, for chick farmers, production costs are driven by the number of fertilized eggs incubated in hatcheries. The cost of fertilized eggs is correlated with the production costs of breeders, which largely consists of the rearing cost of parent stock. Based on the responses of poultry farmers in our survey, we observed that although a fundamental determinant of profitability, feed costs are not the source of price fluctuations in the industry. First, although feed costs witnessed an upward trend over the past decade but in contrast to chick and broiler prices, the changes in feed prices were fairly constant in the short run. Second, poultry farmers maintain a reasonable inventory of feed stock at any given time (usually for one production cycle and at times for several months), limiting the impact of contemporaneous changes in feed costs on production decisions in the short run. Lastly, due to the competitive nature of poultry markets, increases (decreases) in production costs translate into lower (higher) production and hence high (low) prices.

Due to the biological nature of the production process, production decisions (quantity supplied in future) are determined to a large extent by expectations about future prices today. Given the relatively large market for chicken products in Pakistan, the lack of cold storage facilities and limited demand for frozen chicken means that production of poultry products takes place continuously throughout the year. For instance, approximately 5 million broilers are slaughtered everyday in Lahore, the provincial capital of Punjab (poultry production hub), to meet demand. However, future prices are highly uncertain
due to the absence of vertical integration, production planning via regional cooperatives or associations, pre-contracted production and agricultural futures markets\textsuperscript{56}. Weak contract enforcement and incomplete risk markets further complicate the production decisions at the farm level. Furthermore, an opaque information environment characterized by lack of timely and accurate data on key variables like parent stock levels, incubated fertilized eggs, broiler placement and consumer demand, limits the usefulness of formal forecasting models. In an uncertain economic environment plagued with numerous institutional voids, farmers in the poultry value chain are very secretive about individual production plans. Consequently, coordination or communication among key players in the supply chain regarding production decisions is almost nonexistent.

Based on the responses of farmers during structured interviews, we observed that chick farmers look at current prices of chicks and broilers whilst formulating future production plans, i.e., current prices of chicks and broilers serve as a proxy for expected future price of chicks and broilers. Their underlying logic was that if chick prices are high (low) today, then chick prices are expected to remain high (low) at the time of realization of planned production due to relatively short chick production cycle. On the other hand, higher (lower) broiler prices today were viewed as an indicator of higher (lower) broiler prices once the chicks hatched 3 weeks from now, implying a higher (lower) demand for chicks and thus higher (lower) chick prices. Likewise, in addition to chick prices, broiler

\textsuperscript{56} In agricultural cooperatives, pervasive in US and other developed countries, retailers generally submit future procurement orders to cooperatives based on forecasted demand. This information is quickly relayed to farmers in the value chain, so that they may adjust production plans accordingly.
farmers employed current broiler prices as a proxy for expected future price of broilers, whilst formulating their production plans.\textsuperscript{57} As a result, broiler farmers increased (decreased) planned production, in view of high (low) current broiler prices under the expectation that the current high (low) price levels will continue into the following weeks. Unsurprisingly, actual chick prices also influence the production decisions of broiler farmers.\textsuperscript{58} For example if chick prices are exorbitantly high, liquidity constrained broiler farmers are compelled to buy fewer chicks, eventually leading to lower production of broilers and hence high broiler prices at the end of production cycle. Though not immediately obvious, the consistency of these observations with the naïve expectations hypothesis is crystallized upon examination of the equilibrium relationships derived from the forthcoming theoretical model.

However a key question remains: under what conditions would rational agents choose backward looking expectations over forward looking expectations? Or, in other words, under what conditions are naïve expectations consistent with economic rationality? In order to answer this question we need to examine the relative costs and benefits of different expectation regimes. Looking at costs first, one can easily conclude that the cost of acquiring relevant information is very high in the prevalent institutional environment

\textsuperscript{57} Note that broiler farmers face no uncertainty regarding chick prices, since they can observe chick prices at the time of production, whilst, chick farmers face uncertainty regarding both chick and broiler prices at the time of production.

\textsuperscript{58} Credit constraints are a likely explanation for the impact of chick prices on broiler farmers’ production decisions. For example, one broiler farmer remarked that chick prices were a fundamental driver of his production decisions. If chick prices were low he simply bought more chicks and hence produced more broilers and vice versa. Credit plays a key role in business model of poultry farmers and latest data shows that banks made net loans of Rs.4 billion in 2011 to the poultry sector and distributed loans of around Rs.3 billion in 2012, a fairly large amount given the size of the poultry sector. But over the last two years financing to poultry farms has fallen short of actual needs. (Dawn 2012)
due to the absence of future markets on poultry products, limited communication and coordination among poultry farmers and lack of access to reliable data on key variables driving demand/supply. In addition to the opaque information environment, low levels of human capital, due to the lack of access to quality education and limited exposure to basic forecasting models, mean that the cost of processing information is also relatively high. Clearly, under such a situation, the relatively high costs of formulating “better” forward-looking expectations outweigh its perceived benefits. Moreover, as we argue in Section 6, if price trajectories are characterized by chaotic behavior, “better” forward-looking expectations offer minimal incremental benefits over “cheap” backward looking expectations. The aforementioned arguments highlight that in the presence of high information costs and chaotic price trajectories, naïve expectations are consistent with both rationality and optimality within a framework of bounded rationality. Consequently, the net benefits of simple forecasting rules of thumb based on backward looking expectation may exceed the net benefits of “expensive” alternatives based on forward looking expectations. However, the former method clearly neglects important information related to the dynamics of agricultural prices.

Furthermore, note that unlike other agricultural commodities, poultry products have very short production cycles of only a few weeks. Given such a short window, the assumption that current prices persist into the future seems quite reasonable. Moreover, continuously updating forecasts over such a short window based on forward looking expectations is both impractical and exorbitantly expensive. Therefore, the materialization of naïve
expectations and the associated cobweb cycles is very likely in agricultural products like poultry, which possesses short production cycles compared to crops. Lastly, many economists acknowledge that assumptions of the rational expectation hypothesis are violated even in highly developed countries (Chavas 1999a, 1999b & 2000). Clearly these stringent assumptions do not hold in the weak institutional environment of less developed countries. Likewise, there is nothing in the empirical literature that supports the pervasiveness of rational expectations/forward looking expectations over naïve expectations. In fact, the balance of empirical evidence seems to favor the latter category. In the following Sections, we use economic modeling, statistical testing and numerical simulations to provide quantitative evidence to support the preceding analysis that has largely relied on qualitative evidence (prior literature, stylized facts, and anecdotal evidence based on surveys) to argue that price fluctuations in Pakistan poultry sector are a manifestation of cobweb cycles.

4.2 Poultry Value Chain—A Simple Model of Vertically Linked Cobweb Markets

In this subsection, we develop a stylized model to capture the optimizing behavior of chick and broiler farmers given the abovementioned institutional features of the Pakistan poultry sector. An interesting feature of the poultry value chain is the interlinked profit functions along with the mutual interdependency between upstream and downstream farmers. These vertical relationships between upstream and downstream agents have been examined extensively in the agricultural economics literature albeit under very different settings. Whereby, at any given point, the demand for intermediate products is derived
from the solution to the profit maximization problem of agents further downstream in the value chain (Gardner 1975). Given the constraint that price data as opposed to quantity data is generally available at reasonable frequencies in less developed countries, we use the abovementioned setup in a dynamic environment to derive empirically testable hypothesis on chick (upstream) and broiler (downstream) price series under the naïve expectations hypothesis.

Let $\omega_t^C$ denote actual chick price at time $t$ and $\tilde{\omega}_{t+l}^C$ represent the expectation of future chick prices $l$-periods (in other words a $l$-period forecast at time $t$) from now, formulated at time $t$. Under naïve expectations: $\tilde{\omega}_{t+l}^C = \omega_t^C$. Similarly, $p_t^B$ denotes the actual broiler price at time $t$ and $\tilde{p}_{t+l}^B$ represents expected price of broilers $l$ periods from now formulated at time $t$. Time lags in our model capture the fact that poultry farmers cannot respond immediately to price signals, instead the response time/delay is a function of the length of the production cycle. Of course the market situation may change over the duration of the production cycle, introducing ex-ante uncertainty into the model. For expository clarity, we assume $\Delta t = 3$ weeks (the chick production cycle) and revert to the original time configurations later in the empirical Section. $q_t^C$ and $q_t^B$ represent the corresponding levels of production at time $t$ for chick and broiler farmers, respectively. The cost functions for chick and broiler farmers are given by $C_1$ and $C_2$ respectively, where $C_i$ is a continuously differentiable, convex function, i.e., $C_i' > 0$ and $C_i'' > 0$. Both chick and broiler markets are competitive thus farmer are price takers. Lastly, $N_1, N_2$ and
denote the total number of chick farmers, broiler farmers and retailers in the sector, respectively\(^5\).

As is often the case with dynamic models involving multiple agents and interlinked payoffs, we proceed to solve for the equilibrium backwards rather than forwards. Notice that due to the biological nature of the broiler production, i.e., rearing of chicks into broilers, production plans need to be formulated in \(t + 1\) but will only be realized in \(t + 3\) (recall that the production cycle of broiler is six weeks, i.e., \(t = 2\) periods since we assumed \(\Delta t = 3\)). Therefore, at time \(t + 1\), a representative broiler farmer solves the following profit maximization problem:

\[
\text{Arg Max}_{(q^B_{t+3})} \pi_{t+3} : q^B_{t+3} \hat{p}^B_{t+3} - q^C_{t+1} \omega^C_{t+1} - C_2(q^C_{t+1})
\]

subject to

\[
q^B_{t+3} = k q^C_{t+1}, 0 < k < 1
\]

In words, the broiler farmer has to decide how many broilers to produce given the price of chicks at time \(t + 1\) and subject to a simple fixed proportions production technology that converts chicks purchased at time \(t + 1\) into broilers at time \(t + 3\) at a conversion rate of \(k\). This technology parameter is assumed to be fixed since reliable estimates of this conversion ratio are easily available from industry reports. Production costs, which consist largely of feed costs, are a convex function of the number of chicks purchased at time \(t + 1\). As mentioned before the broiler market in Pakistan is a live bird market, and

\(^5\)In the section on numerical simulations, we will use the relative size of counter parties in a given market to incorporate the effects of any bargaining power on price fluctuations.
in the absence of vertical integration or production contracts, broiler farmers have to sell
their produce at the going market rate. Therefore, given the time lag between formulation
of production plans and realization of production, the expectation of future broiler prices
plays a key role in determining the optimal level of broiler production.

Given that $C_2'$ is always invertible, we can simply substitute in the broiler production
function into the profit equation and use the Hotelling’s Lemma to get the optimal supply
curve for broiler farmers\(^{60}\):

$$\frac{\partial \pi_{t+3}}{\partial q_{t+3}} = \bar{p}_{t+3}^{B} - \frac{\omega_{t+1}^{C}}{k} - C_2' \left( \frac{q_{t+3}^{B}}{k} \right) = 0 \Rightarrow q_{t+3}^{B} = k(C_2')^{-1}[k\bar{p}_{t+3}^{B} - \omega_{t+1}^{C}]$$

Note that since $C_2$ is convex, so $C_2'$ is an increasing function by definition and the inverse
of an increasing function is also increasing. As a result, it is straightforward to observe
that the quantity of broilers produced is increasing in price expectations in period $t + 3$
and decreasing in the price of chicks, i.e., the input price.

As mentioned before, in our institutional environment, there are no future contracts on
either broilers or chicks, the poultry sector is not vertically integrated and binding
contracts are seldom enforceable. Given this settings, and in light of the literature
reviewed in Section 2, along with the anecdotal evidence collected from field work

\(^{60}\) Note that the convexity of cost function insures that the first order condition is a sufficient condition for
optimality since $\frac{\partial \bar{p}_{t+3}^{B}}{\partial q_{t+3}^{B}} \geq 0$ if $(k\bar{p}_{t+3}^{B} \geq C_2' \left( \frac{q_{t+3}^{B}}{k} \right) + \omega_{t+1}^{C})$ and $\frac{\partial^2 \pi_{t+3}}{\partial q_{t+3}^{B}^2} < 0$. 

154
(interviews and surveys of poultry farmers) in Pakistan, naïve expectations seems a reasonably justified expectation regime in the poultry sector. Interestingly, the academic literature lends support to this expectation regime in the poultry sector e.g. even in a highly developed country like U.S, Chavas (1999a) empirically estimates a structural model based on joint profit maximization and finds that approximately 91% of poultry farmers expectations are consistent with naïve expectations. By definition, the naïve expectation hypothesis implies that $\tilde{p}_{t+3}^B = p_{t+1}^B$ here, i.e., current prices are expected to continue into the future. We substitute this into the optimal supply curve of a representative farmer, assume homogeneity and aggregate over the $N_2$ broiler farmers in the poultry sector to arrive at the aggregate broiler supply function at time $t + 3$:

$$Q_{t+3}^{BS} = \sum q_{t+3}^B = kN_2(C_2')^{-1}[kp_{t+1}^B - \omega_{t+1}^c]$$

Assuming a negatively sloped broiler retail demand curve for $N_3$ homogenous retailers is given by $F(p_{t+3}^B)$, where $F' < 0$, we can define aggregate demand for broilers at time $t + 3$ as $Q_{t+3}^{BD} = N_3 F(p_{t+3}^B)$. Now recall that the chicken market in Pakistan is predominantly a live bird market with limited cold storage facilities. In the absence of inventory or trade, current demand and supply determines the market clearing price. Therefore we simply equate aggregate quantity demanded and supplied for broilers in time $t + 3$, i.e., $Q_{t+3}^{BD} = Q_{t+3}^{BS}$, to get:

$$N_3 F(p_{t+3}^B) = kN_2(C_2')^{-1}[kp_{t+1}^B - \omega_{t+1}^c]$$
Assuming \( F \) is invertible and after some simplifications, we get the following recursive broiler price equation:

\[
p_{t+3}^B = F^{-1}\left(\frac{kN_2}{N_3} \left(C_2'^{-1}\right)(kp_{t+1}^B - \omega_{t+1}^c)\right)
\]

Since this equilibrium relationship holds for all time \( t \), we can express it as time delay difference equation given by:

\[
p_t^B = F^{-1}\left(\frac{kN_2}{N_3} \left(C_2'^{-1}\right)(kp_{t-2}^B - \omega_{t-2}^c)\right)
\]

(1)

Note that since \( F \) is a decreasing function, \( F^{-1} \) is also a decreasing function. Using this result along with the fact that \( (C_2'^{-1}) \) is an increasing function, it is straightforward to arrive at the following comparative static results via the chain rule\(^61\):

\[
\text{Result – I: } \frac{\partial p_t^B}{\partial p_{t-2}^B} < 0
\]

\[
\text{Result – II: } \frac{\partial p_t^B}{\partial \omega_{t-2}^c} > 0
\]

Both results are intuitive. Result-I represents the standard cobweb phenomenon, i.e., assuming naïve expectations, if prices were high when production decisions were made (time \( t - 2 \)), then prices will be low in time \( t \) due to the resulting supply glut and vice versa. The vertically linked nature of the poultry production process is driving Result-II, e.g. if price of chicks was high when production decisions were made (time \( t - 2 \)) then broiler farmers will reduce procurement of chicks, leading to lower production of broilers in time \( t \) and hence higher broiler prices.

\(^61\)The composition of a decreasing function and an increasing function is always a decreasing function.
In order to close the model and fully specify the dynamics of broiler prices, we need to understand the dynamics of chick prices. Upstream prices play a key role in determining the supply of the final downstream product, i.e., broiler farmers cannot produce broilers without chicks! Consequently, prices at different levels of the value chain are interlinked, representing a coupled system of difference equations. A failure to account for this facet of agricultural markets can lead to erroneous conclusions.

We follow essentially the same steps to derive the difference equation for chick prices. Proceeding backwards, the chick farmer’s profit maximization problem at time $t$ can be written as:

$$\text{Arg Max}_{q_{t+1}} \pi_{t+1}: q_{t+1}^C \tilde{a}_{t+1}^C - C_1(q_{t+1}^C)$$

Chick farmers simply need to decide how many chicks to produce next period. In light of the arguments mentioned in the previous subsection, we do not account for parent stock dynamics in our model and simply assume unconstrained production of chicks with a production lag of 1 period (i.e., 3 weeks). Given $C_1'$ is invertible, first order condition yields the supply curve for the chick farmers:

$$\frac{\partial \pi_{t+1}}{\partial q_{t+1}^C} = \tilde{a}_{t+1}^C - C_1'(q_{t+1}^C) = 0 \Rightarrow q_{t+1}^{C,s} = (C_1')^{-1}(\tilde{a}_{t+1}^C)$$

As expected the quantity of chicks supplied in period $t + 1$ is increasing in the expected price of chicks in the next period because $(C_1')^{-1}$ is increasing function. Now, assuming
chick farmers are homogenous and summing over the $N_1$ chick farmers, we get the aggregate supply curve of chicks under naïve expectations ($\tilde{\omega}^t_{c+1} = \omega^t_c$):

$$Q^c_{t+1} = \sum q^c_{t+1} = N_1(C'_t)^{-1}(\omega^t_c)$$

As pointed out previously, chick prices and broiler prices are closely interrelated. Anecdotal evidence based on field work also suggests that broiler prices play a key role in the current production decisions of chick farmers. This is not surprising since higher broiler prices will have a positive effect on the willingness to pay of broiler farmers for chicks. The resultant higher demand for chicks will translate into higher chick prices. Consequently, expectations about the (derived) demand for chicks at time $t+1$, formulated in period $t$ impact the optimal production decision of chick farmers.

Following the standard method for analyzing vertically linked markets, we solve the broiler farmers profit maximization problem to derive the input (chick) demand at time $t+1$. Substituting the production function into the profit equation and applying Shephard’s Lemma, the optimal demand for chicks is given by:

$$\frac{\partial \pi^t_{t+3}}{\partial q^c_{t+1}} = k\tilde{p}^B_{t+3} - \omega^c_t - C'_2(q^c_{t+1}) = 0 \Rightarrow q^c_{t+1} = (C'_2)^{-1}(k\tilde{p}^B_{t+3} - \omega^c_{t+1}).$$

Clearly, the demand for chicks increases with the expected broiler prices in time $t+3$. Since chick farmers anticipate expected demand for chicks by broilers farmers at the time of formulating production decisions, i.e., time $t$, therefore, under naïve expectations we have $\tilde{p}^B_{t+3} = p^B_t$. Thus, the aggregate demand for chicks in time $t+1$ under the naïve expectation hypothesis is given by:
Because chick farmers sell all their chicks to broiler farmers, we simply use the market clearing condition and equate aggregate quantity demanded of chicks with aggregate quantity supplied at time $t+1$, i.e., $Q_{t+1}^{c,s} = Q_{t+1}^{c,d}$:

$$N_1(C_1')^{-1}(\omega_1^c) = N_2(C_2')^{-1}(kp_t^B - \omega_{t+1}^c)$$

After some algebra and re-indexing of the time subscripts as before (since the equilibrium relationship holds for all time $t$), we get the following difference equation for chick prices:

$$\omega_t^c = kp_{t-1}^B - C_2' \left( \frac{N_1}{N_2} (C_1')^{-1}(\omega_{t-1}^c) \right) (2)$$

Since the composition of two increasing functions is increasing, we arrive at the following intuitive comparative static results for the chick prices difference equation:

$$Result - III: \frac{\partial \omega_t^c}{\partial \omega_{t-1}^c} < 0$$

$$Result - IV: \frac{\partial \omega_t^c}{\partial p_{t-1}^B} > 0$$

Result-III is the standard outcome in cobweb models, i.e., under the naïve expectation hypothesis, if prices were high at the time production plans were formulated then prices will be low at the end of the production period due to an oversupply and vice versa. In a vertically linked value chain, result-IV represents the positive effect of high broiler prices on the demand for chicks and vice versa. More specifically, broiler farmers are willing to pay higher prices to chick farmers in view of high broiler prices in the previous period,
under the (naïve) expectation of benefiting from these higher broiler prices in future. Likewise, chick farmers can successfully bargain over higher chick prices if broiler prices were high in the previous period.

Together equation (1) & (2) represent a coupled system of time-delay difference equations that determine the trajectory of prices under the naïve expectation hypothesis. Since we do not account for the long run profit considerations, whereby the number of chick farmers, broiler farmers and retailers are endogenously determined by the zero profit or free entry condition, thus, Model A is a representation of short run price dynamics only:

\[ \begin{align*}
\text{Model A} &- \left\{ \begin{array}{l}
\hat{p}_t^B = F^{-1}\left( \frac{kN_2}{N_3} (C_2')^{-1}(kp_{t-2}^B - \omega_{t-2}^C) \right) \quad (1) \\
\hat{\omega}_t^C = kp_{t-1}^B - C_2' \left( \frac{N_1}{N_2} (C_1')^{-1}(\omega_{t-1}^C) \right) \quad (2)
\end{array} \right. \\
\end{align*} \]

Like all economic models, this model is a simplified depiction of reality that aims to only capture the essential mechanisms driving price fluctuations, while ignoring auxiliary yet potentially important factors like capacity constraints, adjustment costs, market power, farmer risk averseness or price stickiness. Nevertheless, given the data limitations, we feel that our modeling approach captures key aspects of agricultural value chains, i.e., vertical linkages, production lags and price uncertainty. At the same time, it provides us with a parsimonious framework to specify and interpret results from an empirical model. More specifically, we seek to empirically test whether results I-IV are confirmed by
actual data, lending support to the theory of endogenous price fluctuations in the Pakistan poultry sector. Therefore, in the next Section, we use actual data to estimate the aforementioned coupled system of time delay difference equations in order to empirically evaluate the validity of results I-IV and thus determine whether or not the observed price fluctuations are consistent with the cobweb phenomena.

5 Empirical Evidence-Naïve Expectations & Cobweb Cycles in the Pakistan Poultry Sector

Up till now, we have presented some qualitative evidence (unique institutional environment of the poultry sector, responses of poultry farmers during structured interviews and stylized facts associated with poultry price data in Pakistan) that lends support to the theory of endogenous price fluctuations (i.e., existence of cobweb cycles) in the Pakistan poultry sector. The primary objective of this Section is to formulate an appropriate econometric model to evaluate the validity of this theory empirically. To this end, we first analyze the time series properties of the data. Thereafter, we develop an econometric methodology to statistically test whether or not the actual price data conforms to the predictions (results I-IV) made by our stylized model of price dynamics in a vertically linked agricultural value chain under the naïve expectation hypothesis.

The unique nature of our dataset lends itself perfectly for this type of analysis. Because estimates from econometric models of price dynamics based on high-frequency data are generally considered to be more reliable compared to estimates based on low-frequency
data (Von-Crammon Taubadel & Loy 1996). The original data comprised of daily prices; however, given the length of the poultry production cycle, using daily data would lead to an exponential rise in the number of estimated parameters. Since the production cycle can be easily divided into weekly increments, i.e., 3 weeks for chicks and approximately 6-7 weeks for broilers, we converted the daily prices into average weekly prices. In addition to generating smoother data, aggregation over weekly periods is also more intuitive. Because Farmers are more likely to use prices over the past few days to formulate (naïve) expectations about future prices as opposed to merely the prices on a given day.

The nature of the production cycle rules out monthly aggregation, since the frequency of aggregation will not match the duration of the production cycle, masking the production dynamics along with the associated production decisions at the farm level. Additionally, with monthly aggregation it will be difficult to pinpoint the “current” price farmers use to form future expectations. Perhaps, the frequency mismatch between the length of production cycle and data aggregation is a key factor behind the (incorrect) rejection of the naïve expectations hypothesis in previous work on price fluctuations in some agricultural markets. Clearly, data at annual or quarterly frequency is not suitable for the evaluation of the naïve expectation/cobweb cycle hypothesis, since low frequency data masks the uncertainty faced by farmers and the dynamics of production decisions at the

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62 For example in an unrestricted model with daily data, we would have to estimate more than 100 parameters, severely compromising the consistency of the estimates. At the same time there was minimal day to day variation in daily prices, e.g. there is no price change on consecutive days for more than 50% of the data in both chick and broiler price series, therefore we do not lose significant information by averaging over weekly intervals.
farm level, although knowledge of both is essential to devise an appropriate empirical test to identify cobweb cycles.

5.1 Time Series Properties of the Data - Tests for Stationarity & Cointegration

It is well known that prices, especially prices of agricultural products, are characterized by non-stationary behavior, i.e., time varying mean, variance or covariance. Therefore, we need to carefully evaluate the time series properties of the data before specifying an econometric model to empirically test results I-IV. Since, OLS estimates based on non-stationary data are usually spurious and standard regression diagnostics are no longer valid. Therefore, we first need to establish whether chick and broiler prices are stationary or non-stationary. In the case of the latter, we also need to check the order of integration of both series to determine whether or not both series are cointegrated. Once we have this information, an appropriate econometric model can be specified to empirically test results I-IV.

In view of the low power of the augmented Dicky Fuller (ADF) unit root test, Elliott et al. (1996) proposed the Dicky Fuller-Generalized Least Square (DF-GLS) unit root test. Their test is identical to the ADF unit root test except that the underlying data is transformed using a generalized least squares (GLS) regression before performing the ADF test. The theoretical literature has shown that DF-GLS unit root test possesses significantly higher power and efficiency compared to the simple ADF unit root test(Ng and Perron 2001 & Perron and Ng 1996). Therefore, we report the test statistic from DF-
GLS unit root test instead of the standard ADF unit root test in table 5. The DF-GLS unit root test shows that both chick and broiler prices are non-stationary, i.e., possess unit roots in levels but are stationary in first differences. This conclusion is supported by a visual analysis of chick and broiler prices line plots presented in figure 10.

<table>
<thead>
<tr>
<th>Table 5 Time Series Properties of Poultry Price Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A-Test for Stationarity: Dicky Fuller-Generalized Least Square (DF-GLS) Unit Root Test</strong></td>
</tr>
<tr>
<td>Levels</td>
</tr>
<tr>
<td>Broiler Prices ($p_t^B$)</td>
</tr>
<tr>
<td>Chick Prices ($p_t^C$)</td>
</tr>
</tbody>
</table>

**B-Test for Cointegration: Johansen (1995) Cointegration Test**

<table>
<thead>
<tr>
<th>Trace Statistic ($r = 1$)</th>
<th>Max Statistic ($r = 1$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broiler prices ($p_t^B$) &amp; Chick prices ($p_t^C$)</td>
<td>12.14**</td>
</tr>
</tbody>
</table>

All statistical tests are based on average weekly prices from June 2008 to June 2015. The data was sourced from Pakistan Poultry Association (North). All prices are in nominal units of the local currency. Note that the null hypothesis in the DF-GLS test is presence of a unit root. Therefore, accepting the null corresponds to non-stationarity while rejecting the null corresponds to stationarity. The Ng–Perron modified Akaike information criterion (MAIC) was used to determine the optimal number of lags in autoregressive models for the DF-GLS unit root test. A restricted trend specification was used for the Johansen (1995) cointegration test based on the Pantula principle (1989), while, the optimal number of lags in the underlying model were based on commonly used information criterion (SBIC & HQIC). Note that $r$ denotes the number of cointegrating vectors under the null, in bivariate system $r$ is either 1 or 0. ***, **, * represent significance at 1%, 5% and 10% respectively.

Based on the ADF test, broiler price series was marginally stationary in levels. This conclusion seemed erroneous because the autocorrelation function showed that the autocorrelations don’t die out as the lags are increased. A clear violation of $\lim_{k \to \infty} \text{Cov}(x_t, x_{t-k}) = 0$, an important property of stationary data. Visual inspection of the line plots in figure-9, also lead one to doubt the conclusion of stationarity.
Given that both series are I(1), we employ the Johansen & Juselius (1990) co-integration test to determine if chick and broiler prices are cointegrated. It is a maximum likelihood ratio test based on the maximal eigenvalue or the trace of the coefficient matrix of the underlying vector autoregressive (VAR) model. The max and trace statistic, reported in panel-B, show that both price series are cointegrated, i.e., move together in the long run\(^6\). This result is intuitive, since one would expect a relationship between input (chick) and output (broiler) prices in the long run.

In light of these findings, an empirical model in price levels in not a viable strategy. A simple vector autoregressive (VAR) model in first differences seems an appropriate choice given the equilibrium relationships derived in the previous Section represent a coupled system of difference equations of chick and broiler prices. But, as we argue later, a bivariate vector error correction model (VECM) is our preferred specification.

5.2 Identification & Empirical Strategy

In the previous Section we used a simple dynamic model of profit maximization with vertical linkages between upstream and downstream farmers to derive difference equations for chick and broiler prices (equations I & II) under the naïve expectation hypothesis. In order to empirically test the comparative static results (I-IV) in an OLS framework we calibrate the underlying model with a quadratic cost function for both type of farmers and a negatively sloped linear retail demand curve for broilers. These

\(^6\) Neither statistic follows a chi-square distribution but critical values are provided by Johansen & Juselius (1990) paper.
functional forms are commonly used in research on cobweb markets in the agricultural economics literature (Onozaki et al. 2000; Dieci and Westerhoff 2009; Dieci and Westerhoff 2012). The comparative static results (I-IV) can also be identified with other more general class of functions satisfying the relevant assumptions by taking a first order Taylor series expansion of the resulting nonlinear system of equations. However, we avoid this approach for the sake of simplicity. Details of the derivation are relegated to Appendix F, but it is easy to see that the comparative static results I-IV are well identified in the resulting system of difference equations:

\[
\begin{align*}
\frac{p_t^B}{b} &= \frac{a}{2bN_3} p_{t-2}^B + \frac{N_2k}{2bN_3} \omega_{t-2}^C \\
\omega_t^C &= kp_{t-1}^B - \frac{N_1}{N_2} \omega_{t-1}^C
\end{align*}
\]

Note that \(a\) denotes the extent/size of the market and \(b\) represents price sensitivity in the linear retail demand function of broilers, all other variables are as defined above.

Since we are primarily interested in the verification or falsification of results I-IV as opposed to point estimates, we estimate the following well-identified system of equations to empirically evaluate the existence of cobweb cycles in the poultry sector after reverting to the actual time configurations based on weekly data:

\[\text{Model B}\]

\[\begin{align*}
\frac{p_t^B}{b} &= \frac{a}{2bN_3} p_{t-2}^B + \frac{N_2k}{2bN_3} \omega_{t-2}^C \\
\omega_t^C &= kp_{t-1}^B - \frac{N_1}{N_2} \omega_{t-1}^C
\end{align*}\]

\[\text{(3)}\]

\[\text{(4)}\]

65 All variables in the above equations are strictly positive, therefore the original comparative static results (I-IV) hold true, i.e., \(\frac{\partial \omega_t^C}{\partial p_{t-3}^B} < 0, \frac{\partial \omega_t^C}{\partial p_{t-3}^B} > 0, \frac{\partial p_t^B}{\partial p_{t-7}^B} < 0 \& \frac{\partial p_t^B}{\partial \omega_t^C} > 0\)

66 Recall that the length of the chick production cycle is 22 days (approximately 3 weeks), whereas the length of the broiler production cycle is 6-7 weeks or twice the length of the chick production cycle. We assume a 7 week production cycle for broilers since it results in a better fit of the model compared to a 6 week cycle.
\[
\begin{align*}
\begin{cases}
    p_t^B = \alpha + \beta_{p,7}^B p_{t-7}^B + \beta_{\omega,7}^B \omega_{t-7}^C + \epsilon_t^B \\
    \omega_t^C = \beta_{p,3}^C p_{t-3}^B + \beta_{\omega,3}^C \omega_{t-3}^C + \epsilon_t^C.
\end{cases}
\end{align*}
\]

Here, the subscript of the parameters represents the underlying lag, while the superscript identifies the relevant price equation (\(B\) for broiler price equation and \(C\) for chick price equation). Since the price data is non-stationary in levels, we cannot estimate this system in levels due to the possibility of spurious estimates. Additionally, standard regression diagnostics are no longer valid if the underlying variables are I(1). Therefore, we simply take first differences of the above-mentioned system and instead estimate a model in first differences. However, we lose significant information due to first differencing, but this loss is offset by the gains derived from the reliability of parameter estimates based on stationary data. At the same time the basic intuition behind results I-IV remains intact in the system of equations specified in first differences\(^{67}\).

\[
\begin{align*}
\begin{cases}
    \Delta p_t^B = \beta_{p,7}^B \Delta p_{t-7}^B + \beta_{\omega,7}^B \Delta \omega_{t-7}^C + \Delta \epsilon_t^B \\
    \Delta \omega_t^C = \beta_{p,3}^C \Delta p_{t-3}^B + \beta_{\omega,3}^C \Delta \omega_{t-3}^C + \Delta \epsilon_t^C
\end{cases}
\end{align*}
\]

More specifically, parameter estimates of \(\beta_{p,7}^B < 0, \beta_{\omega,7}^B > 0, \beta_{p,3}^C > 0\) and \(\beta_{\omega,3}^C < 0\) will lend support to the existence of cobweb cycles. Obviously, other factors beyond expectations of chick and broiler prices impact the production decisions of poultry farmers and hence actual prices. To improve the fit of the model and reduce the likelihood of omitted variable bias, we describe the key factors influencing poultry prices along with their relevant proxies in our empirical model in the next subsection.

\(^{67}\)Parameter estimates from a model specified in levels and in first differences have identical interpretation in a linear model.
5.2 Model Specification-Incorporating Additional Explanatory Variables

In the Section on poultry farm economics, we documented that feed costs comprise a large portion of production costs in the poultry sector. The price of poultry feed is linked to prices of primary agricultural commodities, whilst overheads at poultry farms are primarily driven by energy and labor costs. Poultry farmers decide how many chicks/broiler to produce based on estimates of rearing costs at the beginning of the production cycle and usually procure an adequate amount of inventory to cover feeding requirements for the duration of the production cycle. In the absence of data on poultry feed costs, which unarguably varies from farm to farm depending on management practices and quality of feed, We use the sensitive price indicator (SPI) at the beginning of a given production cycle as a (noisy) proxy for production costs (or more aptly rearing costs) during the production cycle in our empirical model\(^\text{68}\). The sensitive price indicator, which is published by Pakistan Bureau of Statistics on a weekly basis, represents a weighted index that comprises prices of different agricultural commodities (corn, wheat, maize, rice etc), energy (petrol, diesel & electricity costs) and labor (wages of workers in the primary/secondary sector). All other things equal, an increase in production costs at the beginning of the production cycle (proxied by an increase in SPI) would result in a decrease in planned production and hence higher prices at the end of the production cycle, assuming competitive markets. Therefore, we expect the coefficient on SPI to be positive and statistically significant in the difference equations of both chick and broiler prices.

\(^{68}\) The SPI series was non-stationary in levels but stationary in first differences, thus we used the first difference of SPI in our econometric specification.
The summer season is particularly harsh in Punjab, the production hub of poultry in Pakistan, with temperatures ranging from 100-120 F (38-50 C). Moreover, chronic energy shortages, amplified by the high demand for the air-conditioning in the summer season, lead to long hours of energy outage. Poultry farmers are adversely affected by the planned load shedding, since broilers and chicks raised in control environments are sensitive to changes in temperature. Due to electricity outages, the temperature in controlled sheds cannot be controlled properly (or controlled at a higher cost via privately generated energy) and excessive heat leads to high rates of mortality. Likewise, due to the rudimentary and often crude transportation methods, mortality rates during delivery of chicks and broilers increase substantially in the summer season. Both factors have an adverse impact on marketed production, leading to higher prices in the summer season. In order to capture this effect, we use a dummy variable, spanning from the beginning of May to the end of July (the hottest months in Punjab), to control for the effect of summer season on the prices of poultry products.

In a country like Pakistan, where diet is deficient in proteins and other sources of animal protein (beef/lamb/fish) are relatively expensive, demand for poultry products is high. Moreover, given that poultry products are a food based commodity, all other things equal, the demand for poultry products remains fairly constant over the year. Nevertheless, Pakistan is also a low income country (GDP per capita of less than $1,000), therefore,

---

69 Extremely cold weather also has an adverse impact on the supply of poultry products. However, the winter season in Pakistan is both short and mild. More importantly, over the last 8 years the winter season has overlapped with Eid-ul-Azha, a period of low demand (hence lower prices) potentially confounding the effect of winter season (low supply and high prices). Therefore, we do not include the winter dummy in the model.
large increase in prices of poultry products result in a significant reduction in demand for chicken. Religious festivities also have an impact on the demand for chicken, especially in predominantly Muslim countries like Pakistan. During Eid-ul-Azha the price of chicken declines due to a reduction in demand, as meat from cattle and lamb slaughtered on these days is stored and consumed for several weeks thereafter. Although our model is primarily geared towards capturing supply side dynamics, in order to capture this key demand side effect in our model, we use a contemporaneous dummy variable to capture the effect of the festive season of Eid-ul-Azha on broiler and chick prices.

However, unlike festivities in the USA & Europe (Thanksgiving, Christmas, Easter etc), festive seasons in Muslim countries like Pakistan are based on the lunar calendar as opposed to the Gregorian calendar. Therefore, we converted the Gregorian calendar into the lunar calendar to capture the effect of Eid-ul-Azha. The Eid-ul-Azha dummy variable in our model corresponds to a 7-week period in a given lunar year, starting 2 weeks prior to Eid-ul-Azha and continuing thereafter for another 5 weeks. Based on

---

70 Ramzan is another important month in Islamic societies, which includes fasting for 30 days, followed by feasting for 3 days. The effect of Ramzan on consumer behavior vis-à-vis poultry prices is less clear, on one hand fasting results in lower consumption. But on the other hand an increase in charitable giving/feeding of the poor during the month, followed by feasting in the final days leads to higher consumption. At the same time over the past decade, Ramzan has overlapped with the summer season; therefore it is difficult to identify the effect of Ramzan on poultry prices due to the supply effect described earlier.

71Eid-ul-Azha is celebrated from 10th-12th of Zul-Hijjah, the 12th month of the Islamic Calendar. Muslims slaughter large animals (cattle, camel, lamb and sheep etc.) to commemorate the sacrifices of Prophet Abraham on this occasion.

72Since, the lunar calendar is based on the moon; the length of a given month is not fixed but depends on moon sighting. Consequently, the months of the lunar calendar shift by approximately 11 days vis-à-vis the Gregorian calendar in a given year, thus lunar months do not correspond to seasons. All lunar month dates were identified based on the Ummul Qura, Saudi Arabian lunar calendar.
survey responses, the reduction in demand of chicken due to an increased consumption of lamb/beef is adequately captured in this 7-week period.

Taking the abovementioned exogenous factors into account and adding controls for any time trends in the difference equations for broiler and chick prices gives us Model I:

\[
\Delta p_t^B = \alpha^B + \gamma^B t + \beta^B_{p,7} \Delta p_{t-7}^B + \beta^B_{\omega,7} \Delta \omega_{t-7}^C + \gamma^B_{t-7} \Delta SPI_{t-7} + D^B_{S} \text{Sum}_t + D^B_{Eid} \text{EidAzha}_t + \epsilon_t^B
\]

\[
\Delta \omega_t^C = \alpha^C + \gamma^C t + \beta^C_{p,3} \Delta p_{t-3}^B + \beta^C_{\omega,3} \Delta \omega_{t-3}^C + \gamma^C_{t-3} \Delta SPI_{t-3} + D^C_{S} \text{Sum}_t + D^C_{Eid} \text{EidAzha}_t + \epsilon_t^C
\]

Given that both chick and broiler prices are endogenously linked, we call Model 1 a restricted VAR model in first differences since intermediate lags are not included. Inclusion of intermediate lags results in a near VAR model in first differences. For the sake of robustness we estimate both versions, to rule out the possibility that estimates from the restricted model are merely statistical artifacts.

However recall that unit root tests revealed that broiler and chick prices are I(1) variables, while the Johansen cointegration showed that both variables are cointegrated. Although Model 1 fully captures the short run dynamics derived from our theoretical model, a failure to control for cointegration in Model I; throws away useful information about the

---

73 Note that SPI was non-stationary in levels but stationary in first differences.
74 A VAR model with different lag length in the underlying equations is called a near VAR model. The same definition applies for a near VECM model.
long run behavior of prices. In order to remove this bias, we employ the Engle & Granger (1987) two-step procedure. Engle & Granger (1987) showed that if two variables are non-stationary in levels but their linear combination is stationary, then this implies that a common stochastic trend is driving these variables. Thus, although the variables may drift apart in the short run, they will tend to converge towards the equilibrium relationship in the long run.

In the first stage of the Engle & Granger (1987) two-step procedure, the long-run (equilibrium) relationship is estimated as a simple OLS regression of the I(1) variables. If the residuals from this regression are stationary, then this implies that the underlying variables are cointegrated. In the second stage, Engle & Granger (1987) showed that if two variables are cointegrated (residuals from stage-1 regression are stationary) then the underlying data generating process can be represented by an error correction model and vice versa. Following this approach, we first estimate the cointegrating (long-run) relationship between broiler and chick prices. Note that given that chicks are a key input for broiler production, it is straightforward to derive a long run relationship between broiler and chick prices, i.e., $p^B = f(\omega^B)^{75}$. Taking a linear approximation of this relationship, we can estimate a simple OLS model, given by $p_t^B = \alpha + \beta \omega_t^C + \mu_t^{76}$. The

---

75 This involves removing time subscripts (and hence expectations) from the profit maximization problem of broiler farmers in Section 3, including long run costs into the model and taking first order conditions. In addition to the first order optimality conditions, the (long-run) zero profit condition will determine the number of farmers and hence total production in a long run equilibrium.

76 Traditional diagnostics, like t-statistics from the cointegrating (long-run) equation are not easily interpretable, because the distribution of the t-ratio in not known due to the presence of I(1) variables. The only purpose of estimating the cointegrating equation is to test whether the residuals are stationary or non-stationary.
resulting residuals: \( \hat{\mu}_t = p_t^B - \hat{\alpha} - \hat{\beta} \omega_t \), are tested for stationarity. The results are summarized below:

<table>
<thead>
<tr>
<th>Table 6 Engle &amp; Granger Cointegration Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>( A)-Estimate the Cointegrating Relationship: ( p_t^B = \alpha + \beta \omega_t + \mu_t )</td>
</tr>
<tr>
<td>( \alpha )</td>
</tr>
<tr>
<td>----------------------</td>
</tr>
<tr>
<td>OLS Estimates</td>
</tr>
<tr>
<td>91.51***</td>
</tr>
<tr>
<td>( B)-Test for Cointegration: ( \hat{\mu}_t = p_t^B - \hat{\alpha} - \hat{\beta} \omega_t )</td>
</tr>
<tr>
<td>( \mu_t )</td>
</tr>
<tr>
<td>-4.23***</td>
</tr>
</tbody>
</table>

All statistical tests are based on average weekly prices from June 2008 to June 2015. The data was sourced from Pakistan Poultry Association (North). All prices are in nominal units of the local currency. Note that the null hypothesis in unit root tests is the presence of a unit root. Therefore, accepting the null corresponds to non-stationarity while rejecting the null corresponds to stationarity. ***, **, * represent significance at 1%, 5% and 10% respectively.

Unit root tests clearly indicate that the predicted residuals are stationary, confirming the earlier conclusion from the Johansen cointegration test. In the second step, Engle & Granger (1987) showed that if the underlying series is cointegrated, OLS estimates from an error correction model are super consistent. An error correction model captures how the underlying endogenous variables behave in the short run consistent with the long-run (cointegrating) equilibrium relationship. To this end, lagged residuals from the cointegrating equation are included in the model to capture the contemporaneous effect of deviations from long run equilibrium on the current dynamics of the endogenous variables. However, note that for the error correction model to be valid, the adjustment
parameters ($\rho$) should be negative, signifying that short-run deviations from the long-run relationship are corrected.

The error correction model applied to our settings can be represented by Model II:

\[
\begin{align*}
\Delta p_t^B &= \alpha^B + \gamma^B t + \beta_{p,t}^B \Delta p_{t-1}^B + \beta_{\omega,t}^B \omega_{t-1}^C + \gamma_{t-1}^B \Delta SPI_{t-1} + D_s^B S_{mt} + D_{Eid}^B E_{Id} A_{tha_t} \\
&+ \rho^B \mu_{t-1} + \epsilon^B_t \\
\Delta \omega_t^C &= \alpha^C + \gamma^C t + \beta_{p,t}^C \Delta p_{t-3}^B + \beta_{\omega,t}^C \omega_{t-3}^C + \gamma_{t-3}^B \Delta SPI_{t-3} + D_s^C S_{mt} + D_{Eid}^C E_{Id} A_{tha_t} \\
&+ \rho^C \mu_{t-1} + \epsilon^C_t
\end{align*}
\]

Model II does not include intermediate lags; doing so would result in a near vector error correction model (VECM) or an unrestricted VECM. As before, for sake of robustness, we will estimate both the restricted and unrestricted versions of Model II.

5.3 Discussion of Estimation Results from Restricted Model

Note that all the variables in Model I and Model II are I(0), allowing us to use OLS estimation and employ standard hypothesis testing methods (t-statistics, F-statistics etc.) and diagnostics to evaluate the estimation results. Since chick and broiler prices are endogenous, we estimate the difference equations in each model simultaneously to capture any contemporaneous correlation between error terms in the chick and broiler price equations. Parameter estimates from the restricted VAR and VECM model are reported in Table 7.
Table 7 Estimates from Restricted Model

<table>
<thead>
<tr>
<th></th>
<th>Model I: Restricted VAR</th>
<th></th>
<th>Model II: Restricted VECM</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chick Price Equation</td>
<td>Broiler Price Equation</td>
<td>Chick Price Equation</td>
<td>Broiler Price Equation</td>
</tr>
<tr>
<td></td>
<td>((\Delta \omega^C_t))</td>
<td>((\Delta p^B_t))</td>
<td>((\Delta \omega^C_t))</td>
<td>((\Delta p^B_t))</td>
</tr>
<tr>
<td>(\alpha)</td>
<td>0.205</td>
<td>-0.252</td>
<td>-0.439</td>
<td>-3.669***</td>
</tr>
<tr>
<td></td>
<td>(0.635)</td>
<td>(0.918)</td>
<td>(0.799)</td>
<td>(1.103)</td>
</tr>
<tr>
<td>(\gamma)</td>
<td>0.00007</td>
<td>0.0010</td>
<td>0.003</td>
<td>0.019***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>(\Delta \omega^C_{t-3})</td>
<td>-0.092*</td>
<td></td>
<td>-0.092*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.052)</td>
<td></td>
<td>(0.052)</td>
<td></td>
</tr>
<tr>
<td>(\Delta p^B_{t-3})</td>
<td>0.096***</td>
<td></td>
<td>0.093**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.037)</td>
<td></td>
<td>(0.038)</td>
<td></td>
</tr>
<tr>
<td>(\Delta \omega^C_{t-7})</td>
<td></td>
<td>0.145**</td>
<td>0.176**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.074)</td>
<td>(0.072)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Delta p^B_{t-7})</td>
<td>-0.076</td>
<td>-0.040</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
<td>(0.053)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Delta SPI^C_{t-3})</td>
<td></td>
<td>0.500*</td>
<td>0.484*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.271)</td>
<td>(0.272)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(\Delta SPI^B_{t-7})</td>
<td></td>
<td>0.717*</td>
<td>0.700*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.388)</td>
<td>(0.375)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Summer_t)</td>
<td>0.642</td>
<td>1.553</td>
<td>0.798</td>
<td>2.419**</td>
</tr>
<tr>
<td></td>
<td>(0.691)</td>
<td>(0.989)</td>
<td>(0.696)</td>
<td>(0.969)</td>
</tr>
<tr>
<td>(EidAzha_t)</td>
<td>-3.019***</td>
<td>-2.107</td>
<td>-3.282***</td>
<td>-3.26***</td>
</tr>
<tr>
<td></td>
<td>(0.923)</td>
<td>(1.322)</td>
<td>(0.941)</td>
<td>(1.29)</td>
</tr>
<tr>
<td>(\mu_{t-1})</td>
<td>-0.026</td>
<td>-0.136***</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.019)</td>
<td>(0.026)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R – Square</td>
<td>5.73%</td>
<td>3.36%</td>
<td>6.28%</td>
<td>9.93%</td>
</tr>
<tr>
<td>Portmanteau Test</td>
<td>8.227</td>
<td>33.377***</td>
<td>7.946</td>
<td>38.351***</td>
</tr>
</tbody>
</table>

Estimates based on weekly prices from June 2008 to June 2015 for a total of 367 observations. The data was sourced from Pakistan Poultry Association (North). All prices are in nominal units of the local currency. Parameter estimates reported adjacent to the corresponding row variables while standard errors provided in the parenthesis below the parameter estimates. Summer denotes a dummy variable representing the period May-July in a given year. EidAzha denotes a dummy variable corresponding to the period 2 weeks before and 5 weeks after the 10th of Zul-Hijjah (12th month in the Islamic calendar). The underlying equations were estimated simultaneously using SUR. The portmanteau (or Q) test for white noise is based on 7 lags of the residuals, where the maximum lag length in the underlying model is used as the criterion for the selection of the number of residual lags to test for zero autocorrelation. Serially uncorrelated errors is the null hypothesis of the portmanteau test. Asterisks indicate statistical significance, where ***, **, * represent significance at 1%, 5% and 10% respectively.
For sake of brevity, we focus on dissecting the empirical estimates rather than delving into the economic intuition behind Results-I-IV, which has been discussed in Section 4. The first column in table 18 reports the Results from the Model 1, i.e., restricted VAR model. Estimates from the chick price equation lend strong support to our theory of endogenous price fluctuations in the poultry sector, i.e., $\beta^c_{p,3}>0$ (Result-IV: $\frac{\partial \omega^c_t}{\partial p_{t-3}^c} > 0$) with a p-value of 0.01 and $\beta^c_{\omega,3}<0$ (Result-III: $\frac{\partial \omega^c_t}{\partial \omega_{t-3}^c} < 0$) with a p-value of 0.07. The estimates from the broiler price equation are also broadly consistent with the theory of endogenous price fluctuations. For instance, $\beta^b_{\omega,7}>0$ (Result-II: $\frac{\partial p^b_t}{\partial \omega_{t-7}^c} > 0$) with a p-value of 0.05 and $\beta^b_{p,7} < 0$ (Result-I: $\frac{\partial p^b_t}{\partial p_{t-2}^c} < 0$), although, the latter coefficient is marginally insignificant at conventional levels of significance (p-value of 0.16). Column 2 reports the results from Model II, the restricted VECM model which accounts for the long run equilibrium relationship between chick prices and broiler prices whilst modeling the short-run price dynamics. The empirical estimates are similar to the results from Model I and broadly consistent with results I-IV.

Perhaps one explanation for the insignificance of $\beta^b_{p,7}$ is the dominance of the effect of actual chick prices on broiler farmers’ production decisions (hence actual broiler prices in future) compared to the effect of ( naïve) expected future prices of broilers on broiler farmers’ production decisions. For example, if a broiler farmer is credit constrained, he may not be able to purchase additional chicks given high chick prices, even though
higher expected prices of broilers in future call for additional procurement of chicks. Other possible explanations for the insignificance of $\rho_{p,7}^B$ include noisy data, factors not captured in our simplified model (market power, bargaining, farmer heterogeneity etc.) or the restrictive functional form assumptions used to identify the comparative static results for the broiler price equation. Nevertheless, it is very unlikely that cobweb cycles in the upstream product do not translate into cobweb cycles in the upstream products, given the fact that market for intermediate goods (chicks) clear and all chicks are eventually converted into broilers. Therefore, we conclude that, taken together, the overall results presented in table 7 lend support to the theory of endogenous price fluctuations, i.e., naïve expectations in the given institutional environment leads to cobweb cycles in the prices of poultry products in Pakistan.

Table 7 also shows that all else equal, an increase in price levels (proxy for feed prices) at the beginning of the production cycle leads to a reduction in planned production and hence higher prices (for both broilers and chicks) at the end of the production cycle. As explained before, this result in intuitive, since farmers facing increasing feeds costs at the beginning of the production cycle curtail planned production resulting in higher prices at the end of the production cycle. Similarly, Eid-ul-Azha, a period characterized by increased consumption of beef/lamb, has a negative effect on the prices of both chicks and broilers, due to a reduction in the demand of chicken during this period. The summer season does not have a statistically significant (adverse) impact on the production of chicks. Although, broiler prices increase significantly during the summer season in lieu of
supply-side reasons, described in Section 4.1. Lastly, broiler prices on average experienced a positive trend over the past decade while chick prices remained stagnant, a finding substantiated by line plots in figure 9. Also, note that the signs of the error correction terms \( \mu_{t-1} \) in Column II are negative for both prices equation, indicating that the VECM is valid representation of the underlying data generating process.

As far as model specification is concerned, controlling for the long run-relationship between chicks and broilers leads to a significant improvement in model fit, especially in the broiler price equation. Bearing in mind that a relatively low R-squared is not uncommon in econometric models specified in first differences, due to the information lost as a result of first differencing the data.

For model diagnostics, we use the portmanteau (or Q) test to check for serially correlated residuals\(^7\). In order to check whether residuals from the underlying empirical model are white noise, the portmanteau test determines whether autocorrelations between residuals at multiple lags are statistically different from zero. Serially uncorrelated residuals (null hypothesis of the portmanteau test) suggest that the model is well specified while serially correlated residuals (alternative hypothesis of the portmanteau test) are an indication of model specification errors. Based on portmanteau test for white noise, we cannot reject the null hypothesis of serially uncorrelated errors in the chick price equation (in both

\(^7\)It is well known that the Durbin Watson Test is not applicable if lagged values of the dependent variables appear on the right hand side of the regression equation. Moreover, the portmanteau test is able to check for serially correlated errors at multiple lags compared to just one lag in the Durbin Watson test.
models), suggesting that the chick price equation is properly specified and hence parameter estimates are valid\textsuperscript{78}. However, we reject the null hypothesis of no residual correlation for broiler equation (in both models), signaling towards possible model specification errors in the broiler price equation.

For the sake of robustness, estimates from the more conventional econometric models, i.e., near VAR model (unrestricted Model I) and the near VECM model (unrestricted Model II) are presented in table 8. The purpose of these tests is to determine whether parameter estimates obtained from the restricted models are statistical artifacts driven by the exclusion of intermediate lags of explanatory variables. Moreover, we also want to see if (possible) specification errors in the broiler equation are mitigated in the unrestricted models.

5.3.1 *Estimates from Chick Price Difference Equation Near VAR & VECM models*

The results from the near VAR and the near VECM model provide further support to the theory of endogenous price fluctuations. All lags of chick prices are negative in the chick price equation in the near VAR model. This implies that periods of increasing prices witnessed during the chick production cycle are followed by periods of decreasing prices (high production) and vice versa, this is a clear manifestation of the classic cobweb effect.

\textsuperscript{78} Note that both comparative static results related to chick prices vis-à-vis cobweb cycles are validated by empirical estimates from the chick price equation.
Table 8 Estimates from Unrestricted Model

<table>
<thead>
<tr>
<th></th>
<th>Model I: Near VAR</th>
<th></th>
<th>Model II: Near VECM</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Chick Price</td>
<td>Broiler Price</td>
<td>Chick Price</td>
<td>Broiler Price</td>
</tr>
<tr>
<td></td>
<td>Equation</td>
<td>Equation</td>
<td>Equation</td>
<td>Equation</td>
</tr>
<tr>
<td></td>
<td>((\Delta \omega_t^C))</td>
<td>((\Delta \omega_t^B))</td>
<td>((\Delta \omega_t^C))</td>
<td>((\Delta \omega_t^B))</td>
</tr>
<tr>
<td>(\alpha)</td>
<td>0.278</td>
<td>-0.056</td>
<td>-0.905</td>
<td>-5.41***</td>
</tr>
<tr>
<td>(\gamma)</td>
<td>-0.0002</td>
<td>0.0003</td>
<td>0.006</td>
<td>0.027***</td>
</tr>
<tr>
<td>(\Delta \omega_{t-1}^C)</td>
<td>-0.037</td>
<td>0.120</td>
<td>-0.054</td>
<td>0.040</td>
</tr>
<tr>
<td>(\Delta \omega_{t-2}^C)</td>
<td>-0.057</td>
<td>0.015</td>
<td>-0.066</td>
<td>-0.043</td>
</tr>
<tr>
<td>(\Delta \omega_{t-3}^C)</td>
<td>-0.096*</td>
<td>0.100</td>
<td>-0.105*</td>
<td>0.042</td>
</tr>
<tr>
<td>(\Delta \omega_{t-4}^C)</td>
<td>0.127*</td>
<td></td>
<td>0.082</td>
<td></td>
</tr>
<tr>
<td>(\Delta \omega_{t-5}^C)</td>
<td>0.062</td>
<td></td>
<td>0.046</td>
<td></td>
</tr>
<tr>
<td>(\Delta \omega_{t-6}^C)</td>
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<td></td>
<td>0.050</td>
<td></td>
</tr>
<tr>
<td>(\Delta \omega_{t-7}^C)</td>
<td>0.181***</td>
<td></td>
<td>0.187***</td>
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</tr>
<tr>
<td>(\Delta p_{t-1}^B)</td>
<td>0.070*</td>
<td>0.256***</td>
<td>0.088**</td>
<td>0.347***</td>
</tr>
<tr>
<td>(\Delta p_{t-2}^B)</td>
<td>0.028</td>
<td>-0.155***</td>
<td>0.050</td>
<td>-0.047</td>
</tr>
<tr>
<td>(\Delta p_{t-3}^B)</td>
<td>0.092**</td>
<td>-0.012</td>
<td>0.115***</td>
<td>0.082</td>
</tr>
<tr>
<td>(\Delta p_{t-4}^B)</td>
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<td>-0.087</td>
<td>-0.007</td>
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</tr>
<tr>
<td>(\Delta p_{t-5}^B)</td>
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<td>-0.018</td>
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</tr>
<tr>
<td>(\Delta p_{t-6}^B)</td>
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<td>-0.098*</td>
<td>-0.039</td>
<td></td>
</tr>
<tr>
<td>(\Delta p_{t-7}^B)</td>
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<td>0.004</td>
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</tr>
<tr>
<td>(\Delta SPI_{t-1})</td>
<td>0.209</td>
<td>-0.025</td>
<td>0.258</td>
<td>0.261</td>
</tr>
<tr>
<td>(\Delta SPI_{t-2})</td>
<td>-0.334</td>
<td>-0.179</td>
<td>-0.299</td>
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<tr>
<td>(\Delta SPI_{t-3})</td>
<td>0.497*</td>
<td>-0.400</td>
<td>0.558**</td>
<td>0.252</td>
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<tr>
<td>(\Delta SPI_{t-4})</td>
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<td>-0.383</td>
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<tr>
<td>(\Delta SPI_{t-5})</td>
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<td>-0.590</td>
<td>-0.468</td>
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<tr>
<td>(\Delta SPI_{t-6})</td>
<td></td>
<td>0.207</td>
<td>0.239</td>
<td></td>
</tr>
<tr>
<td>(\Delta SPI_{t-7})</td>
<td></td>
<td>0.669*</td>
<td>0.770**</td>
<td></td>
</tr>
<tr>
<td>(Summer_t)</td>
<td>0.567</td>
<td>1.86**</td>
<td>0.732</td>
<td>2.54***</td>
</tr>
<tr>
<td>(EidulAzha_t)</td>
<td>-3.039***</td>
<td>-1.229</td>
<td>-3.527***</td>
<td>-2.56**</td>
</tr>
<tr>
<td>(\mu_t)</td>
<td></td>
<td>-0.046**</td>
<td>-0.191***</td>
<td></td>
</tr>
<tr>
<td>R – Square</td>
<td>7.51%</td>
<td>16.18%</td>
<td>8.77%</td>
<td>23.58%</td>
</tr>
<tr>
<td>Portmanteau Test</td>
<td>9.399</td>
<td>0.496</td>
<td>8.992</td>
<td>1.29</td>
</tr>
</tbody>
</table>

Continued
Furthermore, as predicted by our model (Result-III: \( \frac{\partial \omega^c}{\partial \omega^c_{t-3}} < 0 \)), only the third lag, i.e., \( \beta^c_{\omega,3} \) is statistically significant, suggesting that farmers use the current chick prices at the beginning of the production cycle to formulate expectation of future prices and hence production plans.

Moving onto the effect of broiler prices on chick farmer production decisions, consistent with Result-IV, i.e., \( \frac{\partial \omega^c}{\partial p^b_{t-3}} > 0 \), we find that \( \beta^c_{p,3} \) is positive and statistically significant. This represents the cobweb effect in a vertically linked market, whereby (naïve) expectation of higher demand in lieu of high current broiler prices induces chick farmers to increase production and vice versa. Note that although the first broiler price lag (\( \beta^c_{p,1} \)) is also positive, its effect is both smaller in terms of magnitude and statistical significance (p-value of 0.09) compared to the magnitude and significance of \( \beta^c_{p,3} \) (p-value of 0.03). The significance of \( \beta^c_{p,1} \) is perhaps driven by the following phenomenon.

First, from the organization of production in poultry sector we know that broiler farmers buying chicks in a given week are the ones who sold broilers in the last week. Therefore,
if broiler prices were high in last week, broiler farmers experienced a positive cash inflow and are now willing to pay a higher price for chicks and vice versa. Another intuitive explanation is that $\beta^C_{p,1}$ denotes the positive effect of last week’s broiler price on the bargaining over chick prices between chick and broiler farmers. For example, if broiler prices witnessed an increase in the last week, broiler farmers are willing to pay chick farmers a higher price in (naïve) expectation of the continuation of current increasing trend. These interpretations are consistent with survey responses, where participants noted that broiler prices served as reference price for transactions between chick/broiler farmers and broiler farmers /retailers.

The effect of feed costs reaffirms findings from the restricted VAR model, i.e., positive and statistically significant $\gamma^C_{t-3}$, whereby high feed prices at the beginning of the production cycle lead to lower production and hence higher prices at the end of production cycle. Interestingly, all intermediate lags of feed price changes are insignificant, suggesting that production plans are made in view of current feed prices only, consistent with the responses of farmers documented in Section 4.1.

Estimates from the chick price equation in the near VECM model present an identical picture albeit at markedly higher significance levels compared to the results from the near VAR model. More specifically, $\beta^C_{\omega,3}$ (Result-III: $\frac{\partial \omega^C_t}{\partial \omega^C_{t-3}} < 0$), is negative and statistically significant (p-value 0.06), $\beta^C_{p,3}$ (Result-IV: $\frac{\partial \omega^C_t}{\partial p^B_{t-3}} > 0$) is positive and statistically
significant (p-value 0.01) and $\gamma^c_{t-3}$ is positive and statistically significant (p-value 0.05). Likewise, coefficients on intermediate lags of all explanatory variables are statistically insignificant expect $\beta^c_{p,1}$, which reflects the role of last week’s broiler prices as the reference price during bargaining between chick and broiler farmers over chick prices. The estimates presented in table 8 clearly show that empirical evidence in favor of cobweb cycles is not merely a statistical artifact, driven by the exclusion of intermediate lags in the restricted model.

Lastly, the negative effect of EidAzha on chick prices remains regardless of model specification, while summer season does not have statistically significant impact on chick prices (via reduced chick production channel) in either model. Note that compared to the restricted VECM model, the error correction term is negative and statistically significant (p-value 0.02) in the near VECM or unrestricted model, an indication that the near VECM is a valid approximation of the underlying data generating process. Also, the higher R-square in the near VECM model, along with smaller standard errors makes it our preferred specification. Although, based on portmanteau test statistic, we cannot the reject the null of uncorrelated residuals in both the near VAR and near VECM models, suggesting that both models are well specified. Overall, empirical estimates presented in table 8 not only corroborate estimates reported in table 7 but in fact further strengthen the argument in favor of endogenous price fluctuations (cobweb cycles) in chick prices.
5.3.2 Estimates from Broiler Price Difference Equation Near VAR & VECM models

We now focus our attention towards the broiler price equations. In the near VECM model, coefficients on all lags of chick prices are insignificant except $\beta_{\omega,7}$, which is not only significant at the 1% level but has a relatively large positive magnitude. Again, this is consistent with result-II ($\frac{\partial p_t^B}{\partial \omega_{t-7}} > 0$) derived from the stylized model of profit maximization by upstream and downstream farmers in a vertically linked agricultural value chain under the naïve expectations hypothesis. Similar results are obtained from estimates of the broiler price equation in the near VAR model, although $\beta_{\omega,4}$ is also marginally significant in this model. In both the near VAR and near VECM model, $\beta_{p,1}$ is positive and highly significant. Similar to chick prices, this effect may represent the fact that last week’s broiler prices serve as reference prices in negotiations between broiler farmers and retailers. Therefore, high prices last week translate into higher prices today and vice versa. Another explanation, drawn from the price transmission literature, is that $\beta_{p,1}$ merely represents the statistical effect of stickiness or inertia in final good (in this case broiler) prices. Since, final good (broiler) prices don’t change abruptly due to the presence menu or transaction costs of relabeling etc. The effect of feed costs on broiler prices mirrors the results from the restricted models, i.e., only $\gamma_{t-7}^B$ is (positive) statistically significant among all the lags of $\gamma^B$. 

184
In the case of result-I (\(\frac{\partial p^B}{\partial p^B_{t-7}} < 0\)), empirical evidence is ambiguous at best. The estimates from the near VAR model offer some support to the cobweb effect. For instance other than \(\beta_{p,1}^B\), all lags of broiler prices are negative, in the near VAR model, consistent with the standard cobweb effect, although only \(\beta_{p,2}^B\) and \(\beta_{p,6}^B\) are statistically significant. However, all lags of broiler prices are statistically insignificant apart from \(\beta_{p,1}^B\) in the near VECM model. In light of the strong empirical evidence in favor of cobweb cycles in chick production (hence prices), it is very unlikely that cobweb cycles in chick prices do not translate into cobweb cycles in the broiler production (hence prices), given that chicks are eventually converted into broilers. Nevertheless, we present three explanations to resolve this conundrum.

First, as argued earlier, the effect of chick prices on broiler farmers’ production decision dominates the effect of future expectation of broiler prices. Second, recall that the production cycle of broilers varies from 6-7 weeks. At the same time, in contrast to chick farmers, broiler farmers have a certain degree of flexibility vis-à-vis timing of the sale of broilers. Therefore, it may be that at times broiler farmers sell their output in the 5\(^{th}\) week to profit from favorable prices while at other times they wait until the seventh week. As a result, the relevant price that is used to form (naïve) expectation about future prices changes from one cycle to another, diluting the predictive power of our empirical model that relies on the identifying assumption of a fixed production cycle of approximately 7 weeks. Consequently, ignoring intermediate lags, as is done in the restricted models, mitigates this bias to an extent, since the cobweb effect of excluded lags is partially
captured by the $7^{th}$ lag. Recall that in the restricted model $\beta_{p,7}^B$ was negative regardless of model specification, although p-values were high but nonetheless within a neighborhood of acceptability. Third, recall that the identification of the comparative static results of the broiler price difference equation was not straightforward, but relied on additional assumptions on the functional forms$^{79}$. Perhaps these restrictive assumptions weaken the effect of broiler price expectations on broiler production (and hence realized prices).

As observed in the restricted models, summer has a positive effect on broiler prices, an effect that seems to be based on the reduction of supply due to higher broiler mortality in hot weather. EidAzha, a period of increased lamb/beef consumption, has a negative effect on broiler prices due to a reduction in the demand of chicken. Likewise, consistent with previous empirical evidence, results in table 6 show that broiler prices have witnessed an upward trend over the past decade while chick prices have remained largely stagnant. Consistent with the prior literature of agricultural production, we also find a higher effect of feed costs on the prices of downstream product compared to the prices of the upstream sector, i.e., $(y_{t-7}^B > y_{t-3}^B$ with p-value of 0.03).

Lastly, regression diagnostics reveal that R-squared increases significantly in the unrestricted model, especially for the broiler price equations. Most importantly, in

$^{79}$ It is straightforward to note that identification of the comparative static results of the chick price difference equation is independent of any assumptions on functional forms, due to the separability of chick and broiler prices. However the comparative static results for the broiler price equations cannot be identified without additional assumptions on the nature of the broiler cost function and the broiler retail demand function due to the fact that broiler and chick price lags are not separable, and their difference is the argument in the RHS.
contrast to the restricted models, we cannot reject the null hypothesis of serially uncorrelated errors in the chick and broiler price equations in both unrestricted models (near VAR or VECM model) based on portmanteau test, suggesting that the unrestricted models are well specified. We arrive at similar conclusions vis-à-vis model specification based on the autocorrelation (ACF) and partial autocorrelation (PACF) functions.

5.3.2 Summary of Empirical Analysis

A simple dynamic model of profit maximization by downstream and upstream farmers in a vertically linked agricultural value chain provides us with a parsimonious theoretical framework to empirically test the theory of endogenous price fluctuations in the Pakistan poultry sector. In general, the empirical estimates based on a unique dataset comprising of weekly farm-gate prices of chicks and broilers from June 2008 to June 2015 lend support to the naïve expectation hypothesis and hence cobweb web cycles. Our findings are robust to different econometric specifications and estimation methodologies. More specifically, estimates from the restricted VAR and the restricted VECM models, derived directly from the theoretical model under the assumption of a quadratic cost function and a linear retail demand curve, are corroborated by estimates from the more conventional near VAR and near VECM models.

In addition to the major results, we also find that higher feed costs (proxied by SPI) at the beginning of the production cycle lead to lower production and hence higher prices at the end of the production cycle for both chick and broiler prices. Furthermore, as predicted
by theory, there is a strong long run relationship between prices of intermediate (chicks) and final (broiler) agricultural products, evidenced by the negative and statistically significant error correction terms in the estimated VECM models, whereby deviations from the long-run equilibrium are periodically corrected in the short run. Lastly, following the burgeoning literature on the effect of Islamic festivals on economic behavior (Gavriilidis et al. 2015 and Seyyed et al. 2005), we convert the Gregorian calendar into the lunar calendar to isolate the demand side effect of EidAzha, a festive period characterized by increased consumption of beef/lamb, on chicken prices. Unsurprisingly, we document a negative effect of EidAzha on broiler and chick prices due to the lower demand for chicken during this season.

Nevertheless, the abovementioned findings are not without important caveats. First, empirical tests of expectation regimes based on aggregate data are indirect by nature and hence inherently weak. Second, in the absence of aggregate output data, empirical tests of cobweb cycles based on price dynamics, derived from an underlying model of vertically linked upstream and downstream farmers, assume that demand behavior for broiler chicken is given. This does not seem like an unreasonable assumption because broiler chicken is a food based commodity with fairly stable demand. At the same time, given the constraint that aggregate price data is usually available at reasonable frequencies as opposed to quantity data, there seems to no other viable alternatives. Third, the empirical tests are based on theoretical results derived from a stylized model with several simplifying assumptions. However, the validity of a model is not judged by its
assumptions but by its ability to explain reality. Therefore in the next Section, we use simulations to examine whether the stylized facts of the actual data can be reproduced by the price dynamics implied generated our theoretical model.

The low explanatory power of empirical models, in particular the restricted models, vis-à-vis poultry prices is another potential source of concern. Although, a relatively low R-squared is not uncommon in models specified in first differences compared to models specified in levels. However, in our context, explanatory power is less of an issue given the fact that we are primarily interested in the verification or falsification of comparative static results as opposed to point estimates. Besides, regression diagnostics based on portmanteau test for white noise reveal that the empirical models are sufficiently well specified. Nevertheless, given the fact that a large body of theoretical literature has shown that, in the presence of non-linearities, chaotic dynamics can arise in simple non-stochastic cobweb markets. Here, chaotic systems are defined as deterministic dynamical systems that generate apparently random data characterized by excessive variability and unpredictability. Therefore, we cannot rule out chaotic dynamics in the underlying system of difference equations as the underlying factor behind the low explanatory power of our empirical models. We examine some of the key issues related to non-linearities and the associated chaotic dynamics in the next Section.

In summary, an econometrician cannot observe the underlying data generating process driving the prices of chicks and broilers in Pakistan and, instead, can only seek
approximation of systematic components in the trajectory of poultry prices that capture empirical regularities in a given dataset. In this regard, few would argue that the overall empirical estimates presented in this Section are inconsistent with the naïve expectation hypothesis and hence the existence of cobweb cycles in the Pakistan poultry sector. At the same time, by imposing restrictions on the estimated parameters, our theoretical framework allows us to circumvent a common critique of empirical research on price dynamics based on standard autoregressive time-series models, i.e., difficulty in “interpreting” parameter estimates due to the inherently atheoretical and often arbitrary structure of autoregressive time-series models. Robustness checks ensure that our findings are not driven by mere statistical artifacts.

6 A Simple Model of Endogenous Price Fluctuations: Numerical Analysis

The evidence presented in the previous Sections clearly illustrates the relevance of the theory of endogenous price fluctuations in explaining price dynamics in the Pakistan poultry sector. However, models and theories are judged upon their predictive ability in the framework of neoclassical economics (Lucas 1980). Therefore, in this Section we employ numerical analysis to examine whether the stylized model of price fluctuations proposed in Section 3 can reproduce the patterns observed in the actual data. However, before delving into the simulations, we draw attention towards some interesting features of the system of difference equations derived from the underlying theoretical model. This understanding is essential to grasp the intuition behind the forthcoming simulation results.
In Section 4 we showed that the system of coupled, time-delay difference equations for chick and broiler prices derived from a simple model of profit maximization by upstream and downstream farmers in a vertically interlinked competitive cobweb agricultural market is given by:

\[
\begin{align*}
    p_t^B &= \frac{a}{b} - \frac{N_2 k}{N_3 b} \left( \frac{kp_{t-6}^B}{\beta} - \frac{\omega_{t-6}^C}{\beta} \right)^{\frac{1}{\alpha - 1}} \\
    \omega_t^C &= kp_{t-3}^B - \left( \frac{N_1 \beta}{N_2} \right)^{\beta - 1} \left( \frac{\omega_{t-3}^C}{\alpha} \right)^{\frac{\beta - 1}{\alpha - 1}}
\end{align*}
\]

Recall that \(\alpha\) and \(\beta\) represent the curvature of the cost functions for chick farmers \((C_1(q_t^C) = (q_t^C)^\alpha)\) and broiler farmers \((C_2(q_t^C) = (q_t^C)^\beta)\) respectively, where \(\alpha > 1\) and \(\beta > 1\) guarantees convexity. The curvature of the cost curves determine whether the underlying model behaves linearly or non-linearly; the model is linear if \(\alpha = \beta = 2\) and is non-linear otherwise. The demand for broiler by retailers is given by \(Q_t^{B,D} = a - bp_t^B\), where \(a > 0\) denotes the extent (or maximum capacity) of a given retailer and \(b > 0\) represents the sensitivity of demand to broiler prices. A fixed proportions production technology, i.e., the conversion rate of chicks into broilers, is represented by \(k \in [0,1]\). Each discrete time interval (or step) in the abovementioned differences equations represent one week. \(N_1, N_2\) and \(N_3\) represent the number of chick farmers, broiler farmers and retailers in the market respectively. Although, we documented that markets for poultry products were competitive, farmer surveys revealed significant bargaining over prices among counter parties in spot markets. Therefore, we use the ratio of the sizes
(within reasonable bounds) of counterparties (chick farmers, broiler farmers and retailers) in a given transaction (chicks or broilers) to capture the effect of bargaining power on poultry price dynamics\textsuperscript{80}. Our stylized model is simple yet powerful, as it captures several key aspects of agricultural markets, including the effects of cost structures, technological advancements, broiler chicken demand and relative bargaining powers of counterparties on poultry price dynamics.

6.1 Brief Overview-Effect of Time Delays on the Behavior of Dynamic Models

Unlike in static models, in dynamic models we are not only interested in the existence of a steady-state but also in its local stability and the global behavior of orbits generated by the underlying model. By and large, the literature on chaotic agricultural cobweb markets is limited to 1-dimensional maps. This simplifies analysis, since standard analytical results on the stability of one-dimensional systems are well known, making characterization of system dynamics fairly straightforward. However, many standard results derived for one-dimensional chaotic maps cannot be easily extended to two-dimensional systems (Sedaghat 2003). Research by Dieci and Westerhoff (2009 and 2012) is one of the few attempts in the agricultural economics literature to study chaotic dynamics in two dimensional systems. But their work deals with a “standard” system of difference equations, i.e., the future state of the system is completely determined by the current state of the system. This is no longer true in difference equations with time delays.

\textsuperscript{80} For example, broiler farmers and chick farmers bargain over chick prices while broiler farmers and retailers bargain over broiler prices at any given time. In the simulations, we keep relative bargaining power low in order to ensure that considerations for imperfect competition don’t arise.
because the evolution of the system is dependent upon both the current and the past state of the system. Consequently, conventional tools used to analyze the behavior of “standard” dynamical systems are not directly applicable to the analysis of systems with time-delays\(^81\).

But, in reality, time delays in feedback mechanisms are frequently encountered in both the natural and social phenomenon. For example, the effect of time delays on the behavior of physical models is extensively studied in engineering sciences, particularly in the discipline of control systems (Zavaeri & Jamshidi 1987). Likewise, time delays are ubiquitous in biological models of cellular automaton, epidemics and population dynamics (Campbell 2007). Compared to other disciplines, the study of time delays in economics has been somewhat neglected over past decades. Nevertheless, analysis of the effects of lagged investment on business cycles and economic growth in the macroeconomics literature, popularly known as the Kaldor-Kalecki model due to Kaldor (1940) and Kalecki (1935), was one of the earliest attempts to study the impact of time delays on the behavior of dynamic models. However, the effects of time delays vis-à-vis transmission of information related to the competitor’s output on the stability of Nash equilibrium in the Cournot model continues to be an active research area in the industrial organization literature (Howroyd & Russell 1984; Chiarella & Khomin 1996; Yassen & Agiza 2003; Hassan 2004 and Elsadany 2010). However, to the best of our knowledge,

\(^81\) Asymptotic stability of linear systems can be analyzed by computing the eigenvalues of the system transition matrix. While eigenvalues of the Jacobian, used to linearize nonlinear systems around the steady state, are employed to study issues related to local stability of nonlinear systems. As will become obvious later, both strategies need to be significantly modified to examine the behavior of dynamical system with time delays.
the effect of time delays on the dynamics of agricultural prices has not been carefully examined in the agricultural economics literature.

So, how do time-delays affect the global behavior of dynamic agricultural commodity models? It turns out that the answer is not straightforward\textsuperscript{82}. Initially, time delays were considered to be a cause of instability. However, later research has shown that this is not always true (Campbell\textsuperscript{2007}). For example Yassen and Agiza (2003) and Elsadany (2010) prove that time delays increase the probability of convergence towards the Nash equilibrium in a Cournot duopoly game. Likewise, Hassan (2004) shows that time delays increase the region of stability in a Cournot duopoly game. However, Howroyd & Russell (1984) find that decreasing time delays increases the likelihood of stability in a Cournot oligopoly game. In fact, Huang (2008) argues that the relationship between the system stability and delays is not monotonic but varies from one case to case.

Nevertheless, Campbell (2007) has identified several qualitative attributes commonly associated with the underlying dynamics of time-delay models. She finds that time delays often lead to delay induced oscillatory behavior created by Hopf bifurcations\textsuperscript{83}. Whereas, other complicated dynamics associated with time-delay models include the existence of

\textsuperscript{82} Although, the continuous time analogue of time-delay difference equations, i.e., time-delay differential equations are used in the vast majority of these applications. Nonetheless, qualitative results related to the effects of time delays on the dynamics of continuous time problems are generalizable to discrete time problems as well.

\textsuperscript{83} In simple words, Hopf bifurcation is used to describe the change in the behavior of an underlying system from a stable equilibrium state to periodic trajectory as a given bifurcating parameter crosses some critical threshold. It is normally associated with purely imaginary eigenvalues. Of course, as mentioned before, adding delays to the model can also lead to the opposite effect, i.e., transition from a periodic solution to a stable equilibrium point.
solutions with multiple frequencies (quasi-periodicity), attractor switching and multi-stability, i.e., coexistence of more than one stable solution (Guckenheimer & Holmes 1983) and switching from one behavior to another as some parameter is varied (Kuznetsov 1995). In a nutshell, time delays significantly impact the behavior of dynamic models and thus, failing to account for time-delays in a model may lead to incorrect conclusions.

Many of the abovementioned features commonly observed in time-delay models are also typically found in chaotic systems. This is not surprising, since the continuous time analogue of time-delay differences equations, i.e., time delay differential equations belong to the class of functional differential equations that are inherently infinite dimensional problems. Thus, although finite dimensional in the strictest sense, the presence of time delays in difference equations also leads to an increase in the dimension of the state-space of the underlying model. 84 The increase in the dimension of the state space of an underlying model comes at the additional cost of both analytical difficulty and complicated dynamics. In fact, current research on linear chaotic operators has confronted the popular view that chaotic behavior can only arise in the presence of non-linearities. For example, Godefroy & Shapiro (1991) in their seminal work proved that a class of linear functions defined on an infinite dimensional state-space is chaotic.

84 A system of discrete time-delay equations can be recast into a system of higher order difference equations and order reductions methods used convert a system of higher order difference equations into a system of first order difference equations in order to perform stability analysis leads to an increase in the dimension of the state-space.
Likewise, Grosse-Erdmann et al. (2011) document several linear operators on an infinite dimensional state-space that behave chaotically.

Even linear time-delay differential equations do not have closed form analytical solutions, except for some special cases, because continuous time-delay systems possess a spatial component in addition to a temporal component. Thus, unlike a system of ordinary differential equations, time delay systems belong to the class of systems with a functional state variable and hence an infinite dimensional state space. As a result, the characteristic equation of time-delay differential equations is a quasi-polynomial with infinite number of roots in the complex plane (Zavaeri & Jamshidi 1987). Consequently, characterization of eigenvalues on the real-imaginary axis, the workhorse of stability analysis, is no longer applicable. Just like the transition matrix, the Jacobian of the system also contains exponential terms, greatly complicating linearization of non-linear systems around the steady state\(^{85}\). Therefore, numerical methods and simulations are usually employed to study the local and global behavior of the continuous time delay systems. Of course, numerical solutions rely on discretization of the infinite dimensional state space of the underlying model into a finite dimensional state-space.

\(^{85}\) The Lypanov-Krasovski functionals, Razumikhin techniques and Padé approximations are some of the commonly used analytical tools to study the stability of systems with a functional state variable, each method with its own pros and cons.
Although the state-space of time-delay difference equations is finite dimensional\(^{86}\), many difficulties remain in studying the dynamics of time-delay system in discrete time. For example, the eigenvalues of the characteristic equation of a system of time delay difference equations are finite. However, due to the presence of power terms in addition to polynomials in the characteristic equation, eigenvalues often cannot be analytically factorized as a function of model parameters (Zavaeri & Jamshidi 1987). Likewise, standard linearization methods based on the Jacobian are no longer applicable. Moreover, the number of eigenvalues is directly proportional to the size or dimension of the state vector corresponding to an arbitrary initial condition, i.e., length of the delay. Therefore, as the length of the delay increases, the analytical study of a system’s eigenvalues becomes cumbersome. Therefore, numerical analysis is often employed to study time-delay difference equations as well. However, due to the discrete-time nature of these problems, a simple forward looking loop can be used to simulate the underlying model in contrast to the complicated algorithms needed to numerically solve a system of time delay differential equations.

In summary, time delays in the feedback mechanisms limit the efficacy of standard analytical tools used in the study of dynamical systems. At the same time, even in linear systems, time delays can result in complicated trajectories including delay induced oscillations, quasi-periodicity, attractor switching and multi-stability. In fact, in the case

\(^{86}\) The state spaces of discrete-time time delay systems is finite-dimensional because the state vector of past values at each instant has a finite number of elements, compared to delay differential equations where the past values have to be defined over a continuous interval with infinite number of sampling points.
of time-delay differential equations, even linear models can behave chaotically due to the existence of an infinite dimensional state-space. These behavioral features of time-delay systems are particularly relevant for agricultural economists interested in the theory of endogenous price fluctuations, an area where delays in feedback mechanisms are (in reality) a rule rather than an exception. Therefore, it will be interesting to see the insights that can be gained from incorporating time delays into cobweb models of agricultural markets, an endeavor that we pursue in the following pages.

6.2 Equilibrium & Stability Analysis

In light of the properties of time-delay systems documented in the previous subsection, we now direct our attention towards examining the equilibrium states and stability of the underlying system of time-delay difference equations. We begin our analysis with the special case of a linear system, i.e., $\alpha = \beta = 2$. Note that in an equilibrium or steady state of the system $p_t^B = p_{t-3}^B = p_{t-6}^B = p^B$ and similarly $\omega_t^c = \omega_{t-3}^c = \omega_{t-6}^c = \omega^c$. Substituting into the system of linear equations and after some algebraic manipulation we get the following equilibrium state:

$$p^B = \frac{2aN_3(N_2 + N_1)}{2bN_3(N_2 + N_1) + N_2N_1k^2}$$

$$\omega^c = \frac{2aN_3N_2k}{2bN_3(N_2 + N_1) + N_2N_1k^2}$$

In Appendix G, we use the single crossing property to prove the uniqueness of the equilibrium state of the underlying model in the more general case, i.e., without imposing the restriction that $\alpha = \beta = 2$. 198
**Proposition 1:** The equilibrium of the coupled time-delay system on the real axis is unique, non-zero and positive.\(^{87}\)

The steady state of possesses several interesting features. First, note that both equilibrium prices are non-zero and strictly positive given the specifications of the parameters in our model. Second, as expected, we have \(p^B > \omega^c\) in equilibrium\(^{88}\). Third, the comparative static results are intuitive e.g. \(\frac{\partial p^B}{\partial a} > 0\) and \(\frac{\partial \omega^c}{\partial a} > 0\), i.e., equilibrium price of broiler and chicks increases if the retail chicken demand curve shifts upwards. \(\frac{\partial p^B}{\partial b} < 0\) and \(\frac{\partial \omega^c}{\partial b} < 0\), i.e., equilibrium price of broiler and chicks decreases if the retail chicken demand curve becomes steeper (consumers become more price sensitive). And fourth, an increase in number of farmers at a given level in the value chain leads to a decrease in equilibrium prices of products at that level due to the decline in relative size vis-à-vis the counterparty in the given transaction (the bargaining power effect), i.e. \(\frac{\partial p^B}{\partial N_2} < 0\) and \(\frac{\partial \omega^c}{\partial N_1} < 0\). These findings lend support to the validity of the underlying model and also highlight that the equilibrium state is economically “relevant”. The abovementioned comparative static results also hold for the more general, non-linear system\(^{89}\).

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\(^{87}\) From a stability perspective if \(\alpha < \beta\), the system blows up and the equilibrium is no longer unique. Nevertheless even if \(\alpha < \beta\), the economically relevant equilibrium state, i.e., on the positive real line is still unique.

\(^{88}\) Since the denominators of the fixed points are equal, comparing the numerators for \(p^B = 2aN_3(N_2 + N_1)\) and \(\omega^c = 2aN_3N_2k\), it is easy to see that \(p^B > \omega^c\) since \(N_2 + N_1 > N_2k\) because \(k < 1\) and \(N_1\) is a positive integer.

\(^{89}\) The comparative statics of the nonlinear model are similar to the results derived from the linear model but require additional and at times considerably more involved algebra. Therefore, given the scope of this paper and for sake of brevity, we choose not to show these calculations here, but are available upon request.
In a dynamic economic model, in addition to the existence of an equilibrium state, researchers are also interested in the stability of the equilibrium. For example, is the equilibrium asymptotically stable? And how does the system respond to small perturbations from the equilibrium state etc.? However, as mentioned before, the tools used to study the stability of “standard” dynamical systems are not directly applicable to time-delay systems due to delayed feedback mechanisms. Nevertheless, economists have developed methods and techniques to analytically study the properties of time-delay difference equations.

A well-known method to examine the stability of time-delay models in the literature is based on the conversion of a system of time-delay difference equations into a sequence of first-order difference equations (Yassen & Agiza 2003; Hassan 2004 and Elsadany 2010). This approach is based upon the fact that a time-delay difference equation is equivalent to a higher order difference equation\(^{90}\). Given an arbitrary \(n^{th}\) order difference equation, it is fairly straightforward to produce a system of \(n\) first order difference equations by defining \(n-1\) new variables for each higher order difference term (Neusser2015). Thereafter, standard tools can be employed to study the stability of the resulting first order system of difference equations. In particular, it has been shown that the original time-delay system is asymptotically stable if and only if, all the eigenvalues of the augmented systems lie within the unit circle in the real-imaginary axis space and vice-versa. More importantly, well known rules pertaining to the eigenvalues of the

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90 The order of a system of difference equation refers to the maximal difference between the highest and lowest time indexes for a given variable in any system of difference equations.
augmented first order system can be used to understand the qualitative behavior of the original time-delay model, i.e., convergence to equilibrium, diversion from equilibrium or oscillations around the equilibrium.

In Appendix H, we apply this method to study the stability in particular and the qualitative behavior in general of the system of linear coupled-time delay difference equations derived from our theoretical model under the naïve expectations hypothesis. For sake of brevity, the details of the computations are relegated to Appendix H, and eigenvalues under suitable calibrations of the model parameters are plotted below.91

Figure 10 System Eigenvalues on Real-Imaginary Axis

Author: The horizontal axis represents the real component of the eigenvalues and the vertical axis represents the imaginary components of the eigenvalues, computed at the baseline parameter values given in Appendix H.

91 Due to the nature of the underlying time-delay system, the roots of the characteristic equation corresponding to the system transition matrix cannot be expressed in terms of the model parameters due to the presence of higher order terms; for details see appendix-H. Therefore we compute the eigenvalues numerically under reasonable calibrations. The details of the calibration under the baseline scenario are provided in the subsection on numerical simulations.
Figure 10 shows that the original system of linear time-delay difference equations is asymptotically stable because the eigenvalues are within the unit circle in the real-imaginary axis space. This is an important finding since an unstable system, i.e., one with trajectories that explode, is not meaningful and in most cases a clear indication that the underlying economic model is invalid. Moreover, it is well known that complex eigenvalues are associated with oscillatory behavior and it is interesting to note that 10 out of the 12 eigenvalues are complex conjugates, with large imaginary components. Qualitatively similar eigenvalues were obtained using different sets of parameter values. A larger imaginary component relative to the real component is an indication of long-lasting oscillations around the equilibrium. The persistent cycles in the underlying time-delay system are clearly highlighted during numerical simulations.

Mathematically, it is important to note that the channel of price cyclicality in the underlying coupled time-delay system is different from the source of cyclicality in a standard one dimensional cobweb market. In the case of the latter, the border line case of an eigenvalue of negative one is driving the cyclical behavior, severely limiting the range of parameter values at which long-term price cycles arise. However, in higher dimensional systems, complex eigenvalues and hence persistent price cycles are associated with a large range of parameter values. The bifurcation diagrams presented in the next subsection clearly illustrate the changes in the behavior of the underlying system.

\footnote{In the extreme case of non-zero imaginary-component but a real component of zero, the equilibrium is called a center point, i.e., perpetual oscillations around the steady state.}
from a unique steady state (|real eigenvalues|<1) to persistent oscillations (complex eigenvalues) in our settings.

Lastly, the abovementioned analysis reveals that the dynamics of a two-dimensional linear time-delay system is equivalent to the dynamics in a 12 dimensional linear first-order system. Naturally, the complexity of system dynamics increases manifold with an increase in the state space of the model. And, although finite dimensional linear systems are never chaotic in theory high-dimensional linear systems can generate complicated behavior in practice, with markedly high sensitivity to initial conditions. High dimensional systems are known to possess several complex eigenvalues, increasing the likelihood that different initial conditions correspond to the manifolds of different eigenvectors and hence produce different trajectories. Moreover, given that initial states cannot be known with certainty, different sets of initial conditions result in different types of behavior which may lead an external observer to incorrectly conclude that the underlying data generating process is nonlinearly chaotic, unstable or changing over time.

Even for linear systems, direct delay-dependent stability criterion cannot be analyzed analytically (barring some special cases) due to the presence of matrix power terms in the characteristic equation (Zavaeri & Jamshidi 1987). Nevertheless, as shown above, indirect methods used to study the stability of linear time-delay systems reveal that our underlying model is asymptotically stable and characterized by cyclical behavior. However, stability criterion independent of delay can be derived analytically in order to
determine whether delays have a stabilizing or destabilizing effect on the underlying model.

Hale et al. (1985) have provided necessary and sufficient conditions of asymptotic stability independent of time delays for a given time-delay system. In Appendix I, we follow the approach of Hale et al. (1985) to prove that independent of time delays, the underlying model is asymptotically unstable since the absolute value of the dominant eigenvalue is greater than one.

**Proposition 2:** The underlying linear time-delay system is asymptotically unstable independent of time-delays because the absolute value of the dominant eigenvalue is greater than 1.

Proposition 2 and results from the stability analysis of the original linear time-delay systems using an indirect state-space augmentation approach lead us to conclude that feedback delays are a source of stability. These findings have important ramifications vis-à-vis the literature on agricultural cobweb markets, which has, by and large, failed to incorporate time-delays into price dynamics.

The objective of this subsection has been to study the fixed points and stability of the underlying system of time-delay difference equations. The analysis has revealed several important features of the model. First, the fixed-point or equilibrium of the original unrestricted model is unique. Second, in the special case of a linear time delay system,
the original model can be rewritten as set of twelve first order difference equations. The eigenvalues of the resulting system reveal that the original time-delay system is asymptotically stable and characterized by cyclical behavior due to the presence of complex eigenvalues with large imaginary components. Lastly, delays have a stabilizing effect on the dynamics of the model or, in other words, make prices inherently unstable by generating oscillatory behavior around the equilibrium state. We now turn to numerical analysis to crystallize the conclusions derived from the analytical analysis in this subsection.

6.3 Numerical Analysis & Simulations

Numerical simulations are commonly employed to study the global dynamics of time-delay models. However, in contrast to the complicated algorithms needed to solve time-delay differential equations, a simple forward looking loop with appropriate model calibrations can be used to trace the trajectories or orbits of time-delay difference equations.

6.3.1 Model Calibrations

We utilize the findings from fieldwork in Pakistan (refer to Section 1 and Section 3 for details), to calibrate the parameters of the model. The production technology of broiler farmers, i.e., the conversion rate of chicks into broiler \((k)\) equals one minus the mortality rate of chicks in a given production cycle. Industry reports (Poultry Research Institute 2012, 2013 and 2014) and interviews with broiler farmers revealed that approximately
5% of the chicks die during the broiler production cycle on average. Therefore, in the baseline model we use $k = 0.95$. Contrary to conventional wisdom, it is well known that the upstream farm sector (chick famers) is relatively more concentrated compared to the downstream farm sector (broiler farmers) in the Pakistan poultry industry. Likewise, the downstream farm sector is more concentrated than the retail sector. Given that industry concentration is inversely related to the number of firms in a sector we use $N_1 = 10$, $N_2 = 11$ and $N_3 = 12$ in the baseline model. As argued before, the size vis-à-vis the relevant counterparty is employed as a proxy for bargaining power on poultry prices.

Lastly, after taking into account the overall economic environment in less developed countries like Pakistan, we assume a relatively elastic demand for broiler chicken because budget-constrained consumers dramatically curtail consumption if prices increase beyond certain thresholds (and vice versa). But at the same time, broiler chicken is a food based commodity and demand for food based commodities is relatively inelastic. In light of these observations, we assume $a = 90$ and $b = 0.45$ in the retail demand curve for broilers in the baseline model. The simulation results showed that these calibrations yield point-price elasticity of demand between $-1\%$ and $-4\%$ and the elasticity of demand equals $-1.85\%$ at the mean broiler price. Anecdotal evidence and responses of consumers during fieldwork support these hypothesized estimates of the price-elasticity of demand.
6.3.2 Chaotic Dynamics

The top-left panel in Figure 11 illustrates the simulated trajectories of chick and broiler prices over time under the linear time-delay system, i.e., $\alpha = \beta = 2$, without an exogenous production shocks. Simulated prices with a production shock of $\mu \sim (0, 0.75)$ each period related to the mortality of chicks, i.e., $\hat{k} = k + \mu$ are shown in the top-right panel. The lower panel shows the corresponding phase-space plots.

**Figure 11 Simulated Prices-Linear Time Delay Models**

Author: From left to right, the top panel shows the line plots of chick and broiler prices from the linear deterministic time-delay model and the linear stochastic time-de lay model, respectively. The baseline model calibrations are $\alpha = 2, \beta = 2, k = 0.95, a = 90, b = 0.45, N_1 = 10, N_2 = 11 & N_3 = 12.$ Where, the red and blue lines represent weekly chick and broiler prices respectively, simulated over a period of 100 weeks after dropping the transient phase associated with initial conditions. The initial conditions for both simulations are identical. The bottom panel shows the corresponding phase-space plots, i.e., plot of $y(t)$ (y-axis) on $x(t)$ (x-axis).

Simulated prices from the deterministic linear time-delay model are characterized by oscillations around an equilibrium state with a fixed amplitude and period. This type of dynamical behavior is consistent with complex eigenvalues with large imaginary
components relative to real components. Moreover, in contrast to the price trajectories derived from standard cobweb models, the simulated prices from the linear time-delay model are smooth and positively autocorrelated. Introducing production shocks with a zero mean into the linear time-delay model results in more realistic random, non-periodic (the amplitude and period is non-constant) yet cyclical dynamic around an equilibrium state. The simulations demonstrate that a simple model of endogenous price fluctuations with exogenous production shocks can generate the stylized features commonly associated with commodity prices, i.e., positive autocorrelation, cyclicality and random variation.

As expected, the corresponding phase-space plots show that the deterministic linear time-delay model possesses a smooth limit cycle and is thus non-chaotic in strictest sense, while the stochastic linear time-delay model does not have a limit cycle due to production shocks in each period. However, it is well known that non-linearities in difference equations can lead to complicated and often chaotic dynamics even in purely deterministic systems. In order to examine the effect of non-linearities on the dynamics of the underlying system of time-delay difference equations we introduce different types of non-linearities into the system by varying the cost function parameters, i.e., $\alpha$ and $\beta$. The resulting price trajectories are shown in figure 12.

The time series plots in the top panel depict bounded, non-periodic orbits which randomly oscillate around an equilibrium state. However, although the orbits are
approximately quasi-cyclical (periods of increasing prices followed by periods of
decreasing prices), the orbits do not possess a constant period or amplitude. Moreover,
the orbits do not show any repeating patterns. This is highlighted in the phase-space plots,
in which price trajectories consist of dense orbits encircling the equilibrium state without
converging to a stable limit cycle or the equilibrium itself. It is well known that the
aforementioned features typify chaotic systems, i.e., deterministic non-linear maps
exhibiting highly complicated, random and unpredictable behavior (Brock 1986). It is
also interesting to note that even the slightest non-linearities, e.g., the scenario at the top-
left of figure 12, leads to chaos. Likewise, different types of nonlinearities generate
completely different price trajectories.

Figure 12 Simulated Prices-Non-Linear Time Delay Model
Author: From left to right, the top panel shows the line plots of chick and broiler prices from different nonlinear deterministic time-
delay models, parameter values for each simulation are given by: (1) $\alpha = 2.5, \beta = 2.1, k = 0.95, a = 70, b = 0.45, N_1 = 10, N_2 =
11 \& N_3 = 12$. (2) $\alpha = 1.75, \beta = 1.65, k = 0.95, a = 1000, b = 6.5, N_1 = 10, N_2 = 10 \& N_3 = 10$and (3)$\alpha = 3, \beta = 2, k = 0.95, a =
70, b = 0.6, N_1 = 10, N_2 = 11 \& N_3 = 12$. The initial conditions for all simulations are identical. The red and blue lines represent
weekly chick and broiler prices respectively, simulated over a period of 100 weeks after dropping the transient phase associated with
initial conditions. The bottom panel shows the corresponding phase-space plots, i.e., plot of $p_2(\text{y-axis})$ vs $p_1(\text{x-axis})$.}
If our model accurately captures the price dynamics in the Pakistan poultry sector, it is more likely that the true data generating process is non-linear and hence chaotic because the linear system of time-delay equations is only a special case of the underlying model. Note that if prices are chaotic and information acquisition is costly, then naïve expectations about future prices are perfectly rational, as explained in detail in Section 3. But is the actual price data chaotic?

Unfortunately, methods to detect chaos in actual data are rudimentary at best. Consequently, most applications of chaos in economics lack an empirical content (Brock 1999). In practice, identification of chaos in real world data employs a battery of statistical tests but the conclusions are seldom definitive. In fact, Sprott (2003) forcefully argues that due to the presence of environmental shocks, it is extremely difficult to disentangle deterministic randomness or chaos from noise in real world data. For example, Chatrath et al. (2002) use numerous empirical tests to determine whether daily futures prices of wheat, corn, soybean and cotton are chaotic. Although they find evidence of non-linear dependence in the price data, they nevertheless fail to conclusively detect chaotic dynamics. Finkenstadt and Kuhbier (1992) arrive at similar conclusions using weekly price data of pigs and potatoes in Germany from 1955 to 1989.

Nonetheless, data generated from chaotic systems often has a certain degree of structure or determinism relative to pure white noise. The BDS test statistic, due to Brock et al. (1987) is commonly employed to detect determinism in a dataset and thus serves as an
ad-hoc test for deterministic chaos in the literature. The BDS test uses the concept of spatial correlation from chaos theory to compute the correlation integral for a given embedding dimension in the actual data and serves as a powerful statistical test for nonlinearities and deterministic chaos (Chatrath et al. 2002; Finkenstadt and Kuhibier 1992). The rejection of the null hypothesis is construed as evidence of deterministic chaos. Details of the related computations and the properties of the test statistic can be found in Brock et al. (1996).

We use, MATLAB code written by Kanzler (1998) to compute the BDS test statistic for the actual chick and broiler price series along with the companion program (Kanzler 1999), to adjust the corresponding p-values for small sample bias. The BDS test statistics for chick and broiler prices are 58.63 and 56.18, respectively, and are both statistically significant at 1%. The rejection of the null-hypothesis suggests that the actual price data is generated by a chaotic system.

However, as mentioned before, the BDS test is not a conclusive test of chaos, but merely suggestive of determinism in the underlying price series. Moreover, as pointed out by Sprott (2003), the confounding effect of environmental noise in real world data makes clean identification of deterministic chaos virtually impossible. Nonetheless, from an econometrician’s perspective, chaotic dynamics severely limit the efficacy of statistical models vis-à-vis long range price forecasts (Chatrath et al. 2002). In fact, if the underlying data is chaotic, then the current price is the “best” prediction of future price,
very much in tune with the naïve expectation hypothesis. This may be one reason for the low explanatory power of the econometric models estimated in Section 5 of this paper.

It is well known that nonlinearities can generate chaotic dynamics, i.e., bounded, non-periodic and dense orbits characterized by sensitive dependence to initial conditions and small changes in parameters. Interestingly, as highlighted in the beginning of this Section, many of these properties are also commonly observed in time-delay models. For example, delay induced oscillatory behavior created by Hopf bifurcations, existence of solutions with multiple frequencies (quasi-periodicity), multi-stability, i.e., coexistence of more than one stable solution (Guckenheimer & Holmes 1983) and attractor switching, i.e., switching from one type of behavior to another as some parameter is varied (Kuznetsov 1995).

Research has also shown that many linear operators on an infinite dimensional state space can generate chaotic data e.g. Godefroy & Shapiro (1991) and Grosse-Erdmann et al. (2011). It is important to note that time delay *differential* equations belong to a class of functional differential equations known to be inherently infinite dimensional problems. Although finite dimensional in the strictest sense, in practice the presence of time delays in linear difference equations leads to an increase in the dimension of the state-space of the underlying model. And it is well known that increases in the dimension of the state space lead to complicated dynamics (as shown in Appendix H).
Although we do not find dense, non-periodic orbits without a limit cycle in simulations of the linear model, we find markedly high sensitivity to initial conditions and small changes in parameter values linear time delay model. Figure 13 shows the simulated price trajectories of the baseline linear time-delay model with different initial conditions. The initial condition vectors for each scenario are sampled from a reasonable range within the domain of chick and broiler prices.

Figure 13 Linear Time Delay Model Sensitive Dependence on Initial Conditions

Author: The figure shows line plots of chick and broiler prices from the linear deterministic time-delay model with calibrations of parameter identical to the baseline model shown in the top left corner of figure 4 but different initial conditions. The red and blue lines represent weekly chick and broiler prices respectively, simulated over a period of 100 weeks after dropping the transient phase associated with initial conditions. The initial conditions for the baseline model shown in figure 4 are \([p, \omega] = ([100 85 79 70 117 105 110], [151 132 135 133 127], [33 53 57 51 43 45])\). Clockwise from left the initial condition vectors for is given by \([[149 141 134 117 105 110], [51 41 39 35 25 21]], [[121 132 135 133 127], [33 53 57 51 43 45]], [[110 110 110 110 110], [36 36 36 36 36]], [[40 44 44 52 58 56], [33 32 32 30 28 19]]\).

Note that although the price trajectories for different initial conditions are qualitatively similar, i.e., oscillations around an equilibrium state, they nevertheless look remarkably
different despite the fact that model calibration is identical to the baseline model. This type of behavior is uncharacteristic of asymptotically stable linear systems. However, as mentioned before, time-delays in the feedback mechanisms add significant complexity to the behavior of otherwise simple linear dynamical systems, even though the underlying linear time-delay system is not chaotic in the strictest sense due to the presence of an observable (but clearly unstable) limit cycle\footnote{However, note that lack of a stable limit cycle or in other words existence of solutions with multiple frequencies (quasi-periodicity) is not in time-delay systems (Campbell 2007).}. Yet, a remarkably high sensitivity to initial conditions points towards “thin” chaos or complicated behavior in the absence of dense, non-periodic orbits. Chaos poses major problems to the discipline of statistical modeling for long-range price forecasts since it is often not possible to precisely identify the “true” initial conditions. And as highlighted in figure 13, small measurement errors in initial conditions can lead to very different price trajectories even in “thinly” chaotic systems.

Intuitively, the abovementioned sensitive dependency to initial conditions is perhaps driven by two factors. First, recall that the dynamics of the underlying 2-dimensional system of linear time-delay difference equations is equivalent to a 12-dimensional system of first order difference equations (see Appendix H for details). Therefore, different initial conditions may be associated with different eigenvalues as they lie on the stable manifold of different eigenvectors, resulting in different, albeit qualitatively similar behavior. Secondly, retarded differential equations, the continuous time analogue of time-delay difference equations are infinite dimensional problems, and, as mentioned before, chaotic behavior of linear functions on an infinite dimensional state-space is well
documented in the literature (Grosse-Erdmann et al. 2011). Although time-delay
difference equations are not infinite dimensional because of a fixed step-size,
nevertheless, as the length of the delay increases, the behavior of a system of time-delay
difference equations approaches that of a retarded differential equation.

Moreover, given that numerical methods used to solve time-delay differential equations
rely on discretization algorithms, a time-delay differential equation is equivalent to a
system of first order difference equations with a very large but finite state-space
dimension. And it is well known that the complexity of system dynamics and in some
cases even emergence of chaotic behavior is directly related to the dimension of the state-
space. Therefore, if retarded linear differential equations can behave chaotically in
principle due to a high dimensional state-space, the same can be expected of linear time
delay difference equations with long time-delays in general. In summary, although
technically finite dimensional, the presence of time-delays in difference equations results
in an increase in the dimension of the underlying state-space, which may potentially lead
to “thin” chaos, as documented in the simulations in figure 13.

The sensitive dependence of chaotic systems to small changes in parameters is studied
with the help of bifurcation diagrams. Bifurcation diagrams illustrate the transitions in the
nature of the limiting behavior of a dynamical system as a parameter of interest is
systematically varied. A bifurcation is said to have occurred if the limiting behavior of
the underlying system is qualitatively different for parameter values on both sides of a
given critical threshold. For example, transition from steady state to periodic state or transition from a periodic state to an unstable state and vice versa. This type of “switching” behavior is well documented in time-delay systems (Kuznetsov 1995). Given the plethora of research on bifurcations in non-linear systems, we again choose to study the bifurcating behavior of the linear time-delay system. We use $k$ as the bifurcating parameter, since it is conveniently bounded between $0 - 1$ by definition and at the same time it possess a meaningful interpretation, i.e., the efficiency of chick to broiler conversion technology. The bifurcation diagram is presented in figure 14$^{94}$.

Figure 14 Bifurcation Diagram of Linear Time-Delay System
Author: The bifurcation diagram is based on following parameter values $\alpha = 2, \beta = 2, a = 90, b = 0.5, N_1 = 10, N_2 = 11 \& N_3 = 12$. To ensure non-negative chick prices values of $k$ were restricted between 0.075 and 1, with an incremental step size of 0.001. To understand the limiting behavior of the system, as is common practice, a transient phase comprising of 50 periods was omitted from the original state vectors comprising of simulated prices over 200 periods.

$^{94}$ Details of computations used for the bifurcation diagram along with the associated MATLAB code are provided in Appendix-J.
The bifurcation diagram reaffirms earlier conjectures about the supposedly chaotic behavior of the underlying system of linear time-delay equations. For instance, the limiting behavior of chick and broiler price trajectories transitions or “switches” from a unique stable equilibrium state into unstable yet periodic oscillatory cycles as $k$ crosses the (approximate) threshold of 0.8. This type of behavior is characteristic of Hopf bifurcations, usually associated with a change from real to imaginary eigenvalues in low dimensional non-linear systems. At the same time it is well known that delay induced oscillations, a commonly encountered feature of time-delay systems; often arise out of Hopf bifurcations (Campbell 2007). The thick lower tail of the bifurcation diagram, corresponding to values of $k$ (approximately) below 0.3, represents the opposite phenomenon, i.e., transition from a oscillatory periodic state to a stable equilibrium state as $k$ increases beyond the (approximate) threshold of 0.3, albeit at a lesser scale.

The above mentioned numerical analysis highlighted several interesting features of the price trajectories generated by the underlying system of time-delay difference equations derived from a simple model of profit maximization by farmers in a vertically linked cobweb market. In a nutshell, the simulated prices exhibit complicated cyclical behavior with and without nonlinearity in the system. For example, the behavior of the system is clearly chaotic in the presence of any nonlinearity as shown by an absence of stable limit cycles. However, although the special case of linear system possesses a stable limit cycle, its dynamical behavior is characterized by sensitive dependence to initial conditions and small changes to parameters. These findings limit the efficacy of long
range statistical price forecasting methods and lend credence to the argument that naïve expectations about future prices are rational in chaotic markets given information acquisition is costly.

6.4 Comparison of Statistical Properties of Simulated and Actual Price Data

As mentioned at the beginning of this Section, the primary objective of numerical simulations is to determine whether the stylized patterns observed in the actual price data can be reproduced by the proposed model. To this end, we compare and contrast the statistical properties of the simulated price data with the actual data to better understand the strengths and limitations of the underlying model of endogenous price fluctuations. The parsimonious structure of the model allows us to look at several scenarios including exogenous shocks to mortality rate, i.e., chick to broiler conversion technology, effect of different types of nonlinearities on price trajectories etc.

Firstly, simple visual inspection of line plots of simulated prices reported in figure 11 and 12 reveal a non-explosive cyclical/quasi-cyclical behavior broadly similar to the strongly cyclical behavior of actual prices depicted in figure 9. Secondly, the average (normalized) variation in chick prices is twice that of broiler prices in both the simulated data and the actual data. The simulated price series also possess sufficiently high, positive first order autocorrelations, comparable to the autocorrelations (approximately 0.9) in the actual price data. This, in particular, is an important finding because negative autocorrelation in standard cobweb models is a common criticism of the theory of endogenous price
fluctuations. Thirdly, the kurtosis is negative in both the price series, although rather high in the simulated data. But simulated broiler prices show negative skewness in contrast to the positive skewness observed in the actual broiler prices, although, simulated chick prices show positive skewness similar to the actual chick price data. It is evident that scenarios 1-3 are the best depiction of the underlying data generating process95.

Table 9 Relevant Statistical Measures of Simulated Price Data

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Coefficient of Variation</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Auto-correlation</th>
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<tr>
<td>1 Broiler-linear deterministic</td>
<td>0.15</td>
<td>-0.23</td>
<td>-1.47</td>
<td>0.75</td>
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<td>-1.50</td>
<td>0.75</td>
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<td>-0.24</td>
<td>-1.20</td>
<td>0.60</td>
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<tr>
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<td>-1.17</td>
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</tbody>
</table>

95Note that it is has already been shown that even a linear-time delay system can be characterized by “thin” chaos, i.e., sensitive dependence to initial conditions and small changes in parameters despite possessing a stable limit cycle. In this case, a linear model is not inconsistent with rationality of naïve expectations.
6.4.1 Model Appraisal: Limitations and Extensions

Taken together, the results from table 9 suggest that, apart from scenario 5, the underlying model generates, to a reasonable extent, the stylized features observed in the actual price data. At the same time, it is clear that the underlying model cannot reproduce the actual price series to a level of satisfactory precision. However, economic models are not expected to reproduce the exact data generating process behind actual commodity prices in the first place. Models of commodity prices are created to shed light on fundamental mechanisms behind price fluctuations whilst capturing the decisions making processes of agents in a specific economic environment. Obviously, this process entails (intentionally) overlooking potentially important factors like capacity constraints, market power, adjustment costs and risk aversion etc.

These weaknesses withstanding, nevertheless, from a theoretical perspective, the major objective of this paper was to examine the effects of vertical linkages and asymmetric production lags (time-delays) in agricultural values chains on commodity price dynamics. Given the data limitations, a deliberate attempt was made to keep the structure of the model as simple as possible in order to ensure that the analytical results derived from the underlying model can be evaluated statistically using real world data. Of course, this simplicity could not be achieved without ignoring some importation factors pertinent to agricultural markets. Therefore, we take some time out here to point out important weaknesses of the underlying model with the intention of pursuing them in future work.
and hopefully succeeding in addressing the shortcomings of the existing model vis-à-vis recreating the original price series.

Firstly, in reality, farmers cannot simply increase/decrease planned production as a best response to favorable/unfavorable changes in prices due to short-run adjustment costs and long-run capacity constraints. Especially in the case of livestock business, planned production is constrained in the short-run by the size of the breeding herd (parent stock in the case of poultry industry). The resulting inertia leads to higher first order autocorrelation in the actual data compared to the simulated data. In a model with nonlinear supply, Onozaki et al. (2000) incorporate the short run effect of adjustment costs by allowing only partial adjustment towards optimal production in response to a given price change. They show that faster adjustment towards optimal production in face of a given price change increases the likelihood of chaotic behavior and vice versa. Incorporating heterogeneous expectations seems like another valuable modification to the baseline model. For instance, Chavas (1999a) and Chavas (2000) find strong empirical evidence in support of heterogeneous expectation regimes in US broiler and beef sectors, respectively. In presence of heterogeneous expectations about future prices, different farmers respond differently to price changes, resulting in comparatively stable production (hence stable prices) and higher first order autocorrelation in actual prices.
Secondly, another limitation of the model is the failure to incorporate long run dynamics into the price trajectories. For instance, a cursory look at figure 9 clearly reveals several vertical shifts (regime switching) in the actual price data over time, consistent with entry and exit of farmers to preserve the long-run zero profit condition. Such vertical shifts are by and large absent from the simulated price trajectories. One way to incorporate long run dynamics into the model is to endogenize the number of chick farmers, broiler farmers and retailers via the free-entry equilibrium condition. Of course, this stratagem entails the inclusion of additional state variables making the analysis much more complicated. Dieci & Weshterhoff (2010) pursue this line of inquiry by using the profit differentials between two horizontally linked cobweb markets to determine the equilibrium number of participating farmers in each market, although the total number of farmers is held to be fixed. Market power, especially in vertically linked agricultural markets, is another pertinent issue that was not considered in our paper. Interestingly, to the best of our knowledge, the effect of market power on the price dynamics in cobweb agricultural markets has not been fully examined in the literature, although the effect of market power on the chaotic dynamics of prices in Cournot-type markets is an active area of research in the industrial organization literature (Yassen & Agiza 2003; Hassan 2004 and Elsadany 2010).

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96Consequently, in order to ensure minimal influence of long-run dynamics on prices, we limit the time-span of simulations to approximately 100-120 periods in the numerical section. This period is approximately equal to two years and in all likelihood long-run dynamics can be assumed to be fixed over such a short duration in practice. Furthermore, we do not compare the statistical properties related to the levels of accrual data due to the aforementioned shifts in the actual prices.
It may also be worthwhile to explore a scenario in which planned production responses to a price increase differs from changes in planned production in response to a price decrease. Because additions to breeding herd in response to favorable price changes will bear fruition vis-à-vis increased production several periods later. On the contrary, the breeding herd may be immediately culled in response to unfavorable expected prices, resulting in relatively faster decline in future production. This effect can be clearly seen in the actual price data depicted in figure 10, whereby prices do not rise and fall at the same “speed”. Anecdotal evidence also suggests that risk averse farmers rapidly decrease production in response to adverse price movements by culling breeding stock or leaving cropland fallow. Interestingly, Boussard (1996) shows that in the presence of risk averse producers, prices depict chaotic behavior and hedging facilities like future markets fail to reduce the magnitude of price fluctuations. Undoubtedly, pursuing this line of enquiry will lead to the introduction of further complexity into the model due to the discontinuities in the production function.

Some important and seemingly important extensions can be easily incorporated into the original model, e.g., adaptive expectations instead of naïve expectations and predetermined percentage of planned production produced at a pre-contracted fixed rate. We choose not to pursue these extensions for sake of brevity with the reasoned belief that incorporating these factors will not have a qualitatively meaningful impact on the existing price dynamics.
7 Conclusion

The behavior of prices of agricultural products is potentially interesting and at the same time complicated due to the interaction of myriad factors, e.g., production delays, expectation regimes, random supply shocks and seasonality of demand. Although commodity prices depict quasi-cyclical behavior, identification of the period and amplitude of cycles is often impossible due to the presence of several unobserved systematic components in agricultural prices, e.g., seasonality of demand and endogenously changing production patterns. Moreover, interactions of continuous random supply shocks and “cobweb” responses of farmers to price changes may lead to periods of relative stability (quasi-periodic cycles) and instability (explosive cycles). Thus, researchers have to be very careful given the numerous pitfalls associated with examining issues related to agricultural commodity prices.

In this paper we integrated research on theoretical models of chaotic cobweb markets with standard econometric tools for analysis of time-series data and insights from extensive fieldwork to examine the underlying reasons behind the price fluctuations in the Pakistan poultry sector. In doing so we have addressed the well-known shortcomings associated with purely theoretical research, empirical work and descriptive studies. For example, though illuminating, theoretical work often fails to adequately consider whether key assumptions of cobweb models hold in practice and statistical relationships derived from empirical work are often devoid of an economic framework, difficult to interpret and often meaningless. Lastly, farmer surveys and interviews lend support to the
conclusions of the paper and provide an interesting context for the research questions. Although we do not claim that the aforementioned pieces of evidences, i.e., qualitative study, empirical estimation, theoretical modeling and numerical simulation, are individually conclusive, their accumulation presents a coherent picture. In summary, we conclude that numerical simulations and empirical analysis lend support to anecdotal evidence in favor of the relevance of the theory of endogenous price fluctuations in the Pakistan poultry industry.

Methodologically, structured interviews were carried out with different stakeholders in the poultry value chain during field work in Pakistan. The primary purpose of this endeavor was to understand the production and price discovery process, particularly the structure of the poultry supply chain, information flows and the economics of poultry farms in Pakistan. Unsurprisingly, we documented significant organizational differences between the supply chain and institutional environment of the poultry sector in Pakistan and USA. Given an understanding of the domestic price formation mechanisms and a review of the literature on price fluctuations, we developed an economic model to derive relationships between chick and broiler prices under naïve expectations, given the constraint that price data is generally available at reasonable frequencies as opposed to quantity data. In contrast to the previous literature on cobweb markets, we explicitly incorporated vertical linkages in poultry supply chain and asymmetric production time-delays into our model of price fluctuations. Thereafter, standard time-series econometric tools are employed to determine whether the actual broiler and chick prices conform to
the predictions made from the underlying model. Lastly, numerical analyses were used to highlight the “strange” behavior of the underlying system of time-delay difference equations. Under reasonable calibrations, simulations reproduced the stylized patterns observed in the real world data, i.e., quasi-cyclical behavior, positive first-order autocorrelation, high variability and negative kurtosis.

The paper makes several key contributions to the literature. Firstly, fieldwork in Pakistan sheds light on the often poorly understood mechanics of agricultural markets in less developed countries. From an economic theory perspective, we extend the literature on chaotic cobweb markets by incorporating two important aspects, which have been largely overlooked by previous research, i.e., vertical linkages in agricultural value chains and the associated asymmetric production delays. We also add an empirical dimension to the otherwise largely theoretical literature on cobweb markets by employing standard time-series econometrics methods to statistically evaluate the comparative static results derived from the underlying model using real-world data. Lastly, our numerical analysis highlights that incorporating linkages between vertically linked farmers and asymmetric production-delays helps overcome commonly cited critiques of cobweb models, i.e., negatively autocorrelated prices and simple, predictable dynamics. These are non-trivial findings because backward looking expectations are boundedly rational if prices are unpredictable, i.e., chaotic and information acquisition is costly.

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97 For example, we find evidence of chaotic behavior, even in the absence of any explicit nonlinearity.
6.1 Policy Implications

In light of the abovementioned findings, we conclude the paper by offering some policy recommendations to mitigate price volatility in the Pakistan poultry sector. The development of future markets on poultry products in Pakistan is highly improbable given the prevalent institutional environment. Therefore, in the short-run, some sort of market intervention is needed to mitigate endogenous price fluctuations. For example, the Pakistani government may fix broiler and chick price over regular periods to ensure that farmers are aware of the expected price and hence future profitability of production plans. This will lead to stabilization of production and hence prices, if done over a significantly long period time, so that both upstream and downstream farmers are able to benefit from predetermined prices. Stabilizing the upstream sector, seldom discussed in policy debates of price fluctuations, is key to mitigating price fluctuations, since a production glut or shortage originates from the upstream sector and feeds into the downstream sector. Increases in the market power of the upstream sector is one way to achieve stabilization of production because a monopolist sets production (and hence prices) such that marginal revenue equals marginal cost. In fact simulations (not reported) revealed that increasing the bargaining power of the chick farmers mitigated the price cyclicality to a large extent. Of course, both of these policies are merely stop-gap solutions and it is well known that market interventions and imperfections leads to significant deadweight loss.

In the long run, policies that promote vertical integration of the entire poultry value chain are perhaps the best solution to the underlying problem of endogenous price fluctuations.
Even basic level integration between hatcheries and broiler farmers can also lead to significant reduction in the observed price volatility. By stabilizing short run supply, storage leads to a significant reduction in price volatility (Mitra & Boussard 2012), especially given the strong seasonal patterns in the demand for broiler chicken in Pakistan. Seasonal swings in demand can have a large impact on current prices, and hence future prices given current prices are used as a proxy of future price. However, this is not possible without engendering a smooth transition from a live-bird market to frozen bird market. Of course, this requires significant investment in cold storage facilities across the poultry value chain along with relevant extension work to educate farmers and consumers about the benefits of frozen chicken over live-chicken98.

At the poultry association level, investments in information systems to collect, process and disseminate relevant poultry data e.g. placement of parent stock, chicks in hatcheries and broilers sold in a given week etc. will go a long way in helping farmers formulate production plans efficiently. However, the success of such systems relies on voluntary information sharing by participating farmers but in the context of developing countries, the incentives to accurately share production information are usually absent.

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98 The Pakistan government was fairly successful in converting customers from consumption of untreated open-milk to packaged milk through extensive advertising campaigns in the 1990s.
Chapter 3

The Declining Value Relevance of Accounting Information and Herding Behavior: Empirical Evidence from an Emerging Stock Market

1 Introduction

As the global economy slowed down at the end of the “dotcom era”, emerging markets in Asia provided a new channel of growth. From 2002 to 2006, Asia’s GDP growth was twice that of the US (Quah 2008). Economic growth led to higher stock returns and trading volumes in local markets. The Karachi Stock Exchange (KSE) exemplified the growth witnessed by stock markets in Asia. The total market capitalization in the KSE increased from $4.9 billion in 2001 to $70.3 billion in 2007 (World Development Indicators 2012). This period coincided with strong GDP growth, macroeconomic stability, low interest rates and high foreign direct investment (FDI). For example, average GDP growth between 2002-2006 was 6.75%, monthly treasury bill rates dropped from 10.25% in September-1999 to 1.21% in July-2003, FDI increased from $474.7 million in 2002 to $6.96 billion in 2007 and foreign remittances reached $5.5 billion in 2007, up from $913.5 million in 2000 (State Bank of Pakistan 2013).

The KSE outperformed better known emerging markets like Brazil, India and China and at the same time the KSE was relatively inexpensive. In 2006, the average price-earnings (P/E) ratio in Pakistan was 12.2 compared to India’s 16.9 (Hussain 2006). Due to the aforementioned factors, the KSE attracted foreign capital and international media coverage.\(^{100}\) At its peak in February 2008, foreigners held an ownership interest in 327 stocks, including more than 49% of the free float in 11 stocks, and total inflow of foreign portfolio investment (FPI) in the previous year amounted to $1.2 billion (Securities and Exchange Commission Pakistan 2008). Figure 15 depicts the growth of the KSE-100 index, a capital weighted index that tracks the performance of the KSE.

In spite of the strong macroeconomic indicators, the KSE’s performance was marred by volatility. For example, in February 2005 the KSE-100 index crossed 8,261 points, a 50% increase on the November 2004 level, but plunged back to 6,860 points in May 2005. Investors suffered losses of approximately $10 billion and a commission was formed to investigate allegations of manipulation. Economists, most notably Khawaja and Mian (2005) claimed that influential brokerage firms engaged in unscrupulous trading activities, similar to a “pump and dump” strategy, to distort the stock market. Based on a unique trade level dataset spanning 1999-2001, they claimed that colluding brokers artificially inflated stock prices by carrying out wash trades.\(^{101}\) Once the stock prices

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\(^{100}\) The Karachi Stock exchange was declared the world’s top performing stock market by Bloomberg Business Week magazine in its edition on 10\(^{th}\) April 2003 and continued to be among the top-5 performing markets for several years. The KSE was also included in the list of top-5 stock markets by CNNMoney 2012. KSE’s exponential yet enigmatic growth was covered by The Economist in June 2013.

\(^{101}\) Wash trades are illegal trading practices, whereby an investor simultaneously buys and sells shares in a given company through two different brokers. Wash trades artificially enhance the trade activity in a stock,
were high enough the colluding brokers simultaneously liquidated their positions, driving
down stock prices and making windfall gains at the expense of other market participants.

Figure 15 KSE-100 Index 1999-2013

Amidst the global financial meltdown, the KSE plummeted in 2008; protests and political
unrest was followed by government intervention in August 2008. A floor was established
and the KSE was frozen for the first time since its inception. Trade based manipulation as
opposed to firm fundamentals was widely believed to be the reason behind the meteoric
rise and the fall of the KSE. Historical evidence provided a basis to these beliefs, since
pervasive price manipulation in the New York Stock Exchange (NYSE) during the 1900s
giving the impression of active trading without any change in beneficial ownership. It is a violation of the
Securities and Exchange Ordinance in Pakistan.

Fundamental analysis involves the utilization of information embedded in current and past financial
statements, in conjunction with industry and macroeconomic data to arrive at a firm’s intrinsic value.
was well documented (Gordon 2000). However, steady growth from 2009 onwards dampened the pessimism permeating from claims of rampant manipulation and in October 2012 KSE-100 surpassed all previous records. Nevertheless, the growth of this emerging stock market continues to attract the attention of economists. Azad et al. (2014), use price-volume relationships to argue that prices in stock markets in India, Pakistan and Bangladesh systematically diverge from fundamentals due to trade based manipulation. On the other hand, Rahman and Hassan (2012) employ a cross country panel dataset to estimate the relationship between variations in stock returns and firm fundamentals. They find that stock prices in emerging stock markets impound a significant amount of firm-specific information.103

The abovementioned economic context and unresolved debates raise interesting questions about the nature of the relationship between stock prices and firm-specific information embedded in the annual, audited financial statements (accounting information) in Pakistan. For example, what types of information are capitalized in stock prices? What is the explanatory power of accounting information vis-à-vis stock returns relative to other emerging markets? How has the value relevance of financial statements changed over time and why? Despite, extensive research on value relevance of accounting information in developed countries, quality research in emerging markets, especially in Pakistan is lacking. In order to address this gap, we study the explanatory power of accounting information vis-à-vis stocks and examine potential mechanisms that may have

103Rahman and Hassan (2012) analyzed the following emerging stock markets: China, India, Indonesia, Korea, Malaysia, Pakistan Philippines, Taiwan and Thailand.
contributed to changes in the explanatory power of accounting information over time e.g. earnings lack of timeliness and changes in earnings quality. Finally, in light of the stylized facts associated with the growth of KSE and the prevalent institutional environment, we examine whether the phenomenon of “herding affected the relationship between accounting information and stock returns. In the absence of a reliable electronic dataset, a commonly encountered barrier to empirical research in emerging stock markets, we meticulously collected data from different publicly available sources to construct a representative panel dataset comprising of 100 firms listed on the KSE from 1999-2011\textsuperscript{104}.

The paper extends the empirical literature in an important emerging market and provides key insights into the phenomenal growth of the KSE over the past decade. First, contrary to the popular hypothesis that growth in KSE was completely superficial and unrelated to firm fundamentals, our empirical results show a nontrivial relationship between stock prices and firm specific, accounting information. Second, in line with the accounting literature, we find a shift in explanatory power from earnings per share to book value per share in case of losses and a negative relationship between stock returns and firm size. However, time-series regressions (year by year regressions) reveal a gradual decline in the explanatory power of accounting information that cannot be explained by changes in earnings quality or the earnings lack of timeliness hypothesis. Lastly, we find strong

\textsuperscript{104} Unfortunately stock price data collected from Thompson Reuters Datastream contained systematic errors prior to 2011, while financial statement data in Thompson Reuters Datastream suffered from missing values and duplication.
evidence in support of “herding”, especially before the global financial turmoil. This suggests that investors focus on market sentiment and overlook firm specific information embedded in financial statements during bullish periods, consequently weakening the relationship between accounting information and stock prices.

The paper is organized as follows; Section 2 describes important features of the stock markets in Pakistan and summarizes findings from the relevant literature. In order to motivate our empirical analysis, we develop a simple conceptual framework to analyze the different types of information capitalized into stock prices in Section 3. This is followed by a description of the dataset. The pros and cons of econometric models commonly employed in the value relevance literature are critically examined in Section 4, followed by a discussion of the estimation results. Section 5 analyses the effect of additional controls to the baseline model. Changes in the explanatory power of accounting information over time are discussed in Section 6 along with potential explanations including changes in earnings quality, the institutional environment and earnings lack of timeliness. Lastly, in order to assess the validity of our theory that “herding” contributed to the decline in the value relevance of accounting information in the KSE we employ the state-space model of Hwang & Salmon (2004) to analyze the existence and evolution of herding in Section 7.
2 Background

The Karachi Stock Exchange (KSE) accounts for 85% of the total stock market turnover in Pakistan, the Lahore Stock Exchange (LSE) and the Islamabad Stock Exchange (ISE) account for the remainder (Iqbal 2012). We use KSE as a proxy for the stock market in Pakistan, as it is the principal stock market in the country (State Bank of Pakistan 2004). The KSE was founded in September 1947 and incorporated shortly afterwards in March 1949. As of 2002, the exchange is fully automated and trading takes place through an electronic system capable of handling 1 million trades a day. The KSE is also a member of the World Federation of Exchanges, the International Organization of Securities Commissions, and the South Asian Federation of Exchanges. The KSE-100 is the benchmark index used to track the performance of the KSE. A market capitalization weighted index, the KSE-100 was introduced in 1991 with a base value of 1000 points and comprises of 100 stocks selected semi-annually from approximately 650 listed firms based on the highest market capitalization.

The stock market in Pakistan was officially liberalized in 1991 but growth did not begin until the early 2000s. The IMF country report (2004) attributed the rapid growth to improved macroeconomic conditions, low interest rates, excess liquidity and improved regulation. Strong growth in corporate earnings reinforced the ‘bull run’, as average earnings of listed firms grew by 26.5% in 2004 and privatization policies led to many successful IPOs of state owned enterprises (SBP Capital Market Review 2004).
According to Iqbal (2012) the return on equity of top firms in Pakistan is among the highest in the world.

From a regulatory perspective, the inception of the Securities and Exchange Commission Pakistan (SECP) in 1997 improved the corporate governance environment. An SECP Corporate Governance Code was adopted in 2002, as a result more than 60 firms voluntarily delisted from the KSE due to the additional burden of compliance with this code. According to the World Bank’s Corporate Governance Country Assessment (2005), Pakistan’s ranking in several categories of corporate governance is above average. Pakistan adheres to the international accounting standards (IAS) and the international financial reporting standards (IFRS) and listed companies are required to comply with IAS by law since 1986 (Ashraf and Ghani 2005). The aforementioned facts highlight that the regulatory and accounting systems in Pakistan are comparable with international standards (US Department of State 2012).

2.1 Stock Prices & Accounting Information

From an information economics perspective, financial statements play an important role in a stock market by reducing information asymmetry among firms and investors. Accounting rules are principally designed to enhance the role of financial statements in firm valuation. According to the conceptual framework of International Accounting Standards (IAS), a major objective of financial statements is to help investors assess the amount, timing and uncertainty of future cash flows. Two additional attributes have
contributed to the widespread use of financial statements in firm valuation\textsuperscript{105}. First, unlike financial press, well-defined accounting principles (IAS, IFRS and GAAP) guarantee minimal divergence in performance measurement across firms.\textsuperscript{106} Second, corporate governance and external auditors provide credibility to the information presented in financial statements.

Whereas, stock prices are a function of a firm’s intrinsic value and noise. Intrinsic value is defined as the conditional expectation of discounted future cash flows and noise refers to deviations of stock prices from intrinsic values due to the presence of noise traders\textsuperscript{107}. Given this framework, stock prices in period $t$ can defined as:

$$P_t = \sum_{\tau}^{\infty} R_e^{-\tau} E_t[C_{t+\tau}] + \varepsilon_t$$

Where $C_{t+\tau}$ represents future cash flows, $R_e$ is the risk-adjusted discount rate, $\varepsilon_t$ is noise and $E_t[.]$ is the conditional expectation operator given information in period $t$.

Future cash flows and the risk profile of a firm are a function of a wide array of variables (or fundamentals) including firm’s current and expected future financial performance, leverage, growth opportunities, industry outlook and the macroeconomic environment.

\textsuperscript{105}From an industry standpoint, the widespread use of price-earnings ratios in relative valuation techniques corroborates the findings of the academic literature.

\textsuperscript{106}International Accounting Standards (IAS) also known as the International Financial Reporting Standards (IFRS) are accounting rules designed to measure and compare the financial performance of listed firms across the globe. The Generally Accepted Accounting Principles (GAAP or US GAAP) are primarily followed in the US.

\textsuperscript{107}There are many different definitions of noise traders in the literature, in our paper noise traders’ refer to market participants who use unsophisticated methods, usually based on market sentiment to formulate their investment strategies, which are not based any type of fundamental analysis and often characterized by excessive trading.
etc. (Fama and Miller 1972). In an ideal setting changes in stock prices in period \( t \) are driven by information flows related to these variables, however, in the real world noise trader demand is an additional driver of stock prices. Therefore in theory, price changes can be divided into two categories: price changes due to information flows related to firm fundamentals and price changes due to information flows unrelated to firm fundamentals, i.e., noise. The former are usually derived from either accounting (financial statements) or non-accounting (financial press) sources of information and are indirectly measurable (to an extent). While information flows related to the latter category are neither observable nor easily measurable, and usually a result of some kind of market imperfection, bias or mechanism that causes stock prices to deviate from firm fundamentals.

2.2 Review of Empirical Literature

Stock prices reflect a large information set, of which accounting information is only a subset (Beaver et al. 1997). Nonetheless, the importance of accounting information in general and earnings in particular in explaining cross-sectional changes in stock prices is well-documented in a vast empirical literature (Ball & Brown 1968; Fama & French 1992; Collins et al. 1997; Francis & Schipper 1999 and Chen & Zhang 2007). Ball and Brown (1968) were the first to empirically test the strength of this relationship as a statistical association between market values and accounting measures. Their influential work demonstrated that accounting earnings contemporaneously capture a portion of the
information set reflected in stock returns, and led to the emergence of voluminous literature popularly known as value relevance research.

Kothari (2001) states that the objective of a value relevance study is to measure the extent of changes in stock returns that can be explained by accounting information over a long period of time or equivalently the ability of accounting information to capture or summate information that enters stock prices. Subsequent research (Easton et al. 1992, Francis and Schipper 1999, Chen and Zhang 2007) validated the early findings of Ball and Brown (1968), most notably Collins et al. (1997) showed that value relevance of financial statements has increased over the past 40 years and claims that accounting information has lost its value relevance are premature. This stream of literature not only argued that accounting information is a key subset of the information set driving changes in stock prices (Beaver et al.1997) but moreover suggested that earnings serve as a proxy for the market’s (unobserved) expectations about future cash flows (Easton & Harris 1991).

Over the years, a large body of value relevance research has employed various empirical models and estimation techniques to measure the degree to which changes in cross-sectional returns can be explained by changes in accounting information in different countries and institutional settings. The extensive literature cannot be summarized in this paper, nonetheless, we highlight key findings relevant to our research objectives.
Several theories have been proposed to explain differences in the predictive power of accounting information across countries and over time. For example, Healy and Palepu (2001) find that the credibility of management disclosures is enhanced by regulators, standard setters and auditors. Similarly, Defond et al. (2007) illustrate that investors don’t view financial statements to be transparent or clear of material omissions in countries with an under developed accounting profession or poor quality of external audits, resulting in lower value relevance of accounting information. Therefore, weak regulatory control and a poor corporate governance environment, leads to low-quality earnings that weaken the relationship between stock prices and accounting information. The positive effect of earnings quality, stock market liberalization, development of legal institutions on the value relevance of accounting information is well documented in the literature (Ali & Hwang 2000; Barth et al. 2008; Cahan et al. 2009). But at the same time, several researchers (Lee 2001; Penman 2003; Dontoh et al. 2004 & Fung et al. 2010) have shown that high levels of noise trading, speculation and investors’ behavioral biases (e.g. irrational exuberance or herding behavior that leads to momentum investing) reduces the explanatory power of accounting information vis-à-vis stock prices.

The growing empirical literature on the value relevance of financial statements in emerging capital markets provides important insights about the role of accounting information in different regions. Al-Sehali and Spear (2004) observe that disclosure of accounting earnings does not cause any significant revisions in the market’s assessment of future cash flows in Saudi Arabia. Graham and King (2000) also report low value
relevance of financial statements in Taiwan and Malaysia, in contrast to the relatively higher explanatory power of accounting information in Korea and the Philippines. On the other hand, the explanatory power of accounting information in the Chinese stock market refutes the perception of inadequate financial reporting standards and widespread speculation (Chen et al. 2001). Likewise, Alali and Foote’s (2012) findings based on an unbalanced panel of 56 firms from 2000-2006 contradicts claims of speculation and market manipulation in Abu Dhabi’s stock market. Anandarajan et al. (2006) and Filip and Raffournier (2010) arrive at similar conclusions using data from the stock markets in Turkey and Romania.

Interestingly, Chen et al. (2001), Ragab & Omran (2006), Anandarajan et al. (2006) and Naceur & Goaied (2004) argue that the lack of competing sources of reliable non-accounting information in China Egypt, Turkey and Tunisia respectively, is a key factor behind the relatively higher value relevance of financial statements compared to more sophisticated, developed stock markets. They suggest that in the absence of an established information intermediation industry (financial analyst reports, earning forecasts, financial press etc.) and the resulting lack of timely, high quality sources of non-accounting information, investment decisions largely reflect publicly available accounting information.
3 Conceptual Framework

Taking into account the abovementioned arguments, we propose a contemporaneous association between accounting information and stock returns. More specifically, changes in stock prices in any given stock market can be expressed as a function of contemporaneous changes in accounting information flows, in particular accounting earnings ($X$)\textsuperscript{108}, other relevant non-accounting information related to firm fundamentals ($Y$) and noise ($\varepsilon$). It is important to note that this relationship does not correspond to an equilibrium asset pricing model based on risk-return tradeoffs. But instead we follow the information capitalization approach proposed by Morck et al (2000) and use (I) to motivate our analysis of the types of information that enter stock prices.

$$
\Delta P_t = f_t(\Delta X_t, \Delta Y_t, \Delta \varepsilon_t)\textsuperscript{109} (I)
$$

In any given stock market the function “$f_t$” maps accounting information contained in financial statements about firm fundamentals into stock prices. As indicated by the time subscript ($f_t$), the strength of the relationship between accounting information and stock returns in a given stock market is not static and changes over time. Moreover, upon examination of (I), one can infer that these changes are driven by the properties of accounting information, relative abundance & quality of non-accounting information and

\textsuperscript{108}The literature has documented the value relevance of many other types of accounting information including book values, total assets, accruals etc. Our focus on accounting earnings is guided by the following realizations: 1) Among the different categories of accounting information there is relatively more emphasis on earnings by investors, especially in less developed stock markets 2) On average, earnings do a better job in explaining cross-sectional stock returns compared to other types of accounting information including reported cash flows and 3) data limitations.

\textsuperscript{109}Investors are interested in changes in stock prices as opposed to mere price levels.
noise levels\textsuperscript{110}. We defer a discussion of each category along with their relative bearing on the explanatory power of accounting information in the KSE to the second half of the paper and instead direct our attention to the primary research question: is KSE a phantom stock market, completely unrelated to firm fundamentals and devoid of economic reality?

3.1 Hypothesis

Given the abovementioned conceptual framework of stock price dynamics, widespread market manipulation will result in systematic deviations of stock prices from intrinsic values and the associated firm fundamentals (Lee 2001). The logic is straightforward, if a stock market is overwhelmingly dominated by market manipulators then changes in stock prices are driven noise instead of information flows related to firm fundamentals. Therefore, all else equal, widespread market manipulation based on pump & dump trading strategies\textsuperscript{111} will lead to systematic deviations between prices and fundamentals. Given the assumption that accounting information is associated with firm fundamentals (as argued above), widespread market manipulation will inevitably reduce the value relevance of financial statements. Because in such a scenario, changes in stock prices are driven by noise and independent of accounting information, consequently, accounting

\textsuperscript{110}Another common explanation for the weak relationship between earnings and stock returns is known as the deficient “GAAP/IAS hypothesis” or more generally value irrelevant noise in financial statements (Kothari 2001). The value irrelevant noise refers to earnings measurement rules that require or allow management to estimate the present value of cash flows in a manner that systematically differs (i.e., without reversing) from the market’s valuation of cash flows (Collins et al., 1994). This value irrelevant noise in financial statements is not priced by the market and weakens the relationship between earnings and returns. We don’t account for this channel in our conceptual framework.

\textsuperscript{111}The success of manipulation schemes based on pump and dump trading strategies rely on positive feedback investors, i.e., traders who buy stocks when prices are rising and sell stocks when prices are falling, clearly this kind of investor behavior is a consistent with our definition of noise trading.
information is not capitalized into stock prices and the explanatory power of accounting information vis-à-vis stock prices is diminished.

Therefore, if Khawaja & Mian (2005) hypothesis that stock prices in KSE are orchestrated by a group of colluding brokers is indeed true then one would expect changes in stock prices to be unrelated (or at least very weakly related) to the firm specific information embedded in financial statements. Before proceeding to an empirical test of this hypothesis we provide a brief description of our dataset.

3.2 Description of Dataset
The dataset comprises of a balanced panel of 100 firms listed on the KSE from 1999 to 2011. A balanced panel spanning over a long horizon was preferred over a shorter unbalanced panel for two reasons. Firstly, from an econometrics standpoint, changes in cross-Sections over time in an unbalanced panel limit the usefulness of comparisons between parameter estimates in the year by year regressions commonly employed in value relevance studies. Secondly, the period from 2002 to 2005 witnessed a high number of IPOs, spurred by the government’s privatization scheme of nationalized industries. The financial economics literature on IPO pricing puzzles (Ibbotson 1975, Allen & Faulhaber 1989, Ritter 1999) points towards the absence of a clear relationship between financial statement information and IPO prices in the years immediately

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112 The same argument applies to unobserved herding levels backed out from the Hwang & Salmon (2004) state space model.
following an IPO. Therefore, IPOs were excluded from the analysis by imposing the constraint of a balanced panel.

Illiquid and closely held stocks are commonly encountered in emerging stock markets.\(^{113}\) The Karachi Stock Exchange is no different. Although a significant percentage of the total listed firms, illiquid stocks make a negligible contribution towards market capitalization and free float. Infrequent trading in illiquid stocks by investors wary of insider information and liquidity premiums result in “stale” prices that do not reflect the information available to the market. Consequently, information about underlying fundamentals contained in the audited financial statements is not embedded in the prices of illiquid stocks. Thus, including illiquid stocks in the dataset will result in an artificial downward bias on the value relevance of financial statements without improving the representativeness of the sample. Historically, the KSE-100 has captured 80-90% of the market capitalization and trading volume in the KSE. Therefore, a conscious effort was made to exclude illiquid stocks from the dataset by selecting stocks from the KSE-100 index\(^{114}\). The dataset is fairly representative of the investment activities in Pakistan and is composed of stocks that satisfy the commonly used criterion of active trading, investor interest and liquidity.

\(^{113}\) The criterion for illiquid stocks: No variation in stock prices for 3 or more months in a given financial year.

\(^{114}\) A one to one correspondence could not be achieved, since the KSE-100 index is recomposed semi-annually. Approximately 70% of the firms included in the dataset have been listed one or more times on the KSE-100 index based on its composition in 2000, 2005 and 2012.
The data was meticulously collected from different publicly available sources of information. Stock prices were retrieved from “Business Recorder”, the leading business newspaper in Pakistan. To compensate for the time lag before audited financial statements are made public, we follow the standard in the literature and use stock price 3 months after financial year end of a given firm to calculate annual buy and hold stock returns. Financial data was retrieved from the State Bank of Pakistan. Lastly, since the financial reporting period of listed firms in Pakistan is not uniform, the financial reporting period for each firm was identified from the respective annual reports of the firms.\(^{115}\) Table 10 reports the summary statistics of the dataset. The average stock return of 14.9% and earnings growth of 25.2% are notable, along with the corresponding standard deviations.

Table 10 Stock Price Data Summary Statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Median</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>P</td>
<td>0.36</td>
<td>5601</td>
<td>143.4</td>
<td>46.71</td>
<td>389.6</td>
</tr>
<tr>
<td>BVPS</td>
<td>1.1</td>
<td>2250</td>
<td>92.1</td>
<td>40.75</td>
<td>198.2</td>
</tr>
<tr>
<td>EPS</td>
<td>-66.2</td>
<td>443.9</td>
<td>21.7</td>
<td>8.3</td>
<td>44.1</td>
</tr>
<tr>
<td>A (millions)</td>
<td>37.4</td>
<td>656,324.8</td>
<td>24,453.8</td>
<td>5,619.7</td>
<td>57,624.4</td>
</tr>
<tr>
<td>r</td>
<td>-88.4%</td>
<td>227.8%</td>
<td>14.9%</td>
<td>3.66%</td>
<td>55.3%</td>
</tr>
<tr>
<td>x</td>
<td>-373.3%</td>
<td>263.1%</td>
<td>11.9%</td>
<td>17.3%</td>
<td>54.9%</td>
</tr>
<tr>
<td>Δx</td>
<td>-245.2%</td>
<td>319.5%</td>
<td>5.45%</td>
<td>1.5%</td>
<td>45.8%</td>
</tr>
<tr>
<td>X</td>
<td>-350%</td>
<td>669.2%</td>
<td>25.2%</td>
<td>11.0%</td>
<td>113.9%</td>
</tr>
</tbody>
</table>

Levels variables are Price(P), earnings per share before tax (EPS), book value per share (BVPS) and total assets (A), all measured in the local currency, i.e., Pakistani rupee, the average exchange rate between 1999-2011 was 1 USD= 65.8 Pakistani rupees, the exchange rate remained relatively stable, with a standard deviation of 11.2 during this period. Other variables are defined as: buy and hold stock return exclusive of dividends \(r_{it} = \frac{P_{it} - P_{t-1}}{P_{t-1}}\). Earnings yield \(\text{yield}_{it} = \frac{\text{EPS}_{it}}{P_{t-1}}\), changes in earnings yield \(\Delta \text{yield}_{it} = \frac{\text{EPS}_{it} - \text{EPS}_{it-1}}{P_{t-1}}\) and earnings growth \(X_{it} = \frac{\text{EPS}_{it} - \text{EPS}_{it-1}}{\text{EPS}_{it-1}}\).

\(^{115}\)Although June is the financial year end of most firms in the sample, September and March were also observed.
4 Value Relevance of Financial Statements: Empirical Models

The price model and the return model are commonly employed to test the value relevance of financial statements, where R-square is the principal measure of the explanatory power of accounting information (Francis and Schipper 1999). The price model and the return model are based on different functional forms and possess different statistical properties; as a result estimates of earnings response coefficients and R-square are often different (Ota 2003). For example Harris et al. (1994) find that the explanatory power of the value relevance regressions for German firms relative to that of U.S. firms is lower for the price model but comparable for the return model. The econometrics of the price and the return models has been the subject of much debate in the literature. A common solution is to utilize both models to ensure that inferences are not sensitive to the econometric specification.

4.1 Price Model

Economists assume that stock price equals the present value of expected dividends. If $d_{t+\tau}$ are future dividends, $R_e$ is the appropriate discount rate and $E_t[.]$ is the conditional expectation operator given information in period t, we can express the price of a firm’s share in period t as:

$$P_t = \sum_{\tau}^{\infty} R_e^{-\tau} E_t[d_{t+\tau}]$$

(1)

116 Both models also capture different aspects of the relationship between accounting information and stock prices, which will become obvious in the following pages.
Ohlson (1995) exploited the clean surplus assumption given in equation 2, to substitute out dividends from equation (1) and express stock price as a function of only accounting information, earnings per share (EPS) and book value per share (BVPS).\footnote{The clean surplus assumption states that dividends reduce book value per share but do not affect current earnings per share.}

\begin{equation}
BVPS_{t+1} = BVPS_t - d_t + EPS_t
\end{equation}

\begin{equation}
Pt = \sum_{\tau} R_{e^{-\tau}}E_t[BVPS_{t+\tau} - BVPS_{t+\tau+1} + EPS_{t+\tau}]
\end{equation}

Thereafter, Ohlson (1995) used an information dynamic to simplify equation 3 and show that stock price can be expressed as a linear function of current earnings and book values.

\begin{equation*}
\textbf{Model 1: } P_{lt} = \alpha_0 + \beta_1 EPS_{lt} + \beta_2 BVPS_{lt} + \epsilon_{lt}
\end{equation*}

Ohlson (1995) received acclaim for establishing a theoretical basis for ad-hoc regressions of stock prices on accounting variables, given the parsimonious assumptions, his paper is widely acknowledged as a classic (Beaver 2002). The model is also intuitively appealing, current earnings reflect information about a firm’s revenue generating abilities and serve as a proxy for future cash flows. While book value per share represents the value of assets in place, analogous to an abandonment option for investors, especially for firms in distress (Collins, et al. 1997; Barth et al. 1998). Moreover, Kothari and Zimmerman (1995) show that unlike the return model which suffers from the attenuation bias the earnings response coefficient ($\beta_1$) in the Price model is unbiased because stock price
reflects the cumulative effect of earnings information, i.e., stock price varies due to both the surprise and stale components of earnings.

We estimate the Price model using the standard method of pooled OLS. For robustness, the two-way fixed effects model is also estimated to control for time invariant firm specific effects and time varying factors. Observations with negative book value per share were excluded and the remaining data was winsorized at the top and bottom 1\% to exclude outliers. Newey-West standard errors were used to correct for heteroscedasticity and autocorrelation in the error term structure. The results are presented in Table 11.

<table>
<thead>
<tr>
<th>Table 11 Price Model Regressions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled OLS Model: $P_{it} = \alpha_0 + \beta_1 EPS_{it} + \beta_2 BVPS_{it} + \varepsilon_{it}$ (A)</td>
</tr>
<tr>
<td><strong>Parameter</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>$\alpha_0$</td>
</tr>
<tr>
<td>$\beta_1$</td>
</tr>
<tr>
<td>$\beta_2$</td>
</tr>
<tr>
<td>Fixed Effects Model: $P_{it} = \alpha_0 + \beta_1 EPS_{it} + \beta_2 BVPS_{it} + \delta_t + \mu_i + \varepsilon_{it}$ (B)</td>
</tr>
<tr>
<td><strong>Parameter</strong></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>$\alpha_0$</td>
</tr>
<tr>
<td>$\beta_1$</td>
</tr>
<tr>
<td>$\beta_2$</td>
</tr>
</tbody>
</table>

$P_{it}$ = Stock price 3 months after the end of financial year of firm i. $EPS_{it}$ = earnings per share before tax in a given financial year. $BVPS_{it}$ = Net assets divided by outstanding shares in a given financial year. $\delta_t$ captures the time-related shocks across firms in a given year and $\mu_i$ accounts for the time-invariant, firm-specific effects, $\varepsilon_{it}$ is white noise. Standard errors provided in the parenthesis below the parameter estimates. Asterisks indicate statistical significance, where ***, **, * represent significance at 1\%, 5\% and 10\% respectively.

An R-square of 61.90\% in the pooled OLS model, shows the high explanatory power of accounting earnings vis-à-vis stock prices. This is not surprising, Easton & Sommers
(2003), report an R-square of 78.2% in the US, Anandarajan et al. (2006) document an R-square of 62.8% in Turkey while and Ragab and Omran (2006) find an R-square of 40.3% based on pooled OLS estimates of the Price model. Teets and Wasley (1996) show that in the presence of cross-sectional differences between firm specific factors, pooled estimation may lead to incorrect inferences in the value relevance regression framework.

We employed an F-test to check whether or not the time invariant firm specific effects in the fixed effects model are significantly different from zero, i.e., tested the null hypothesis $\mu_1 = \mu_2 = \ldots = \mu_t = \ldots = \mu_{100} = 0$. With an F-test statistic of 6.71 (significant at the 1% level) the null hypothesis was rejected, thus statistical insignificance of $\beta_2$ in the pooled OLS may indeed be driven by time invariant firm fixed effects. Once we control for firm fixed effects, the results in panel-B show that coefficient on BVPS is positive and statistically significant, consistent with the literature (Beaver 2002).

Generally from an econometrics standpoint, coefficient estimates that control for fixed effects are more reliable compared to pooled OLS estimates. Nevertheless, the R-square from pooled OLS regressions is the primary measure of the value relevance of accounting information in the literature because the pooled OLS model contains only accounting information as the explanatory variables. While, the fixed effects model accounts for both firm and time specific factors in addition to accounting information, resulting in a higher R-square. Therefore, for the remainder of this paper, we report results from both the pooled OLS and the fixed effect models, R-square from the former is a measure of value
relevance of financial statements and coefficients estimates from the latter provide a robustness check.

Despite the theoretical basis and intuitive appeal of the Price model, financial economists have increasingly questioned the implausibly high explanatory power of accounting information vis-à-vis stock prices. Easton (1999) shows that a positive relationship between stock prices, earnings and book values in a price model may be driven by scale effects rather than value relevance of accounting information. For example, larger firms generally have a higher stock price, earnings per share and book values per share and vice versa, have also argued that the statistical association between prices and explanatory variables in price-level regression is due to the spurious effect of scale. They show that the omission of a scale factor results in an upwardly biased R-square and expressing variables on a per-share basis does not overcome this problem. Similarly, Brown et al. (1999) observe that the higher R-square observed in price model regression compared to return model regressions in the US data is due to the presence of scale effects in the price model. Thus, scale effects and the risk of spurious regression limit the usefulness of estimates of value relevance of financial statements derived from the Price model.

Before estimating the Return model, we turn our attention to a series of intuitive methods that can be used to overcome the scale effects in the price model. We highlight simple manipulations that not only overcome the econometric problems associated with the Price model but at the same time effectively transform it into the Easton & Harris (1991) return
model. In doing so, we are able to emphasize the often ignored relationship between the 
Price and Return models and their common theoretical foundations.

Given that stock prices series are usually non-stationary and OLS estimates based on 
non-stationary variables are generally spurious. First, we take first differences to 
transform the specification of the price model given in equation (4). The method of first 
differencing is commonly used in the economics literature to solve problems associated 
with non-stationarity, especially in time series data. First differencing also mitigates the 
scale effects in the price model to an extent (Easton 1999). Intuitively as well, investors 
are more interested in changes in stock prices as opposed to mere price levels.

\[ P_{it} - P_{it-1} = \beta_1 (EPS_{it} - EPS_{it-1}) + \beta_2 (BVPS_{it} - BVPS_{it-1}) + \epsilon_{it} - \epsilon_{it-1} \quad (5) \]

Since changes in book values have no direct economic intuition, we invoke the clear 
surplus assumption in equation (2) to substitute out book value per share (BVPS) from 
equation (5), i.e., \( BVPS_{it} - BVPS_{it-1} = EPS_{it} - DIV_{it} \). Collecting earnings terms and 
simplifying we get:

\[ P_{it} - P_{it-1} + \beta_2 DIV_{it} = \beta_2 EPS_{it} + \beta_1 \Delta EPS_{it} + \bar{\epsilon}_{it} \quad (6) \]

Lastly, we deflate the model by the lagged stock price. Brown et al. (1999), Barth and 
Kallapur (1996) and Christie (1987) have all shown that lagged price is the most effective 
cure of scale effects in the price model.

\[ \left( \frac{P_{it} - P_{it-1} + \beta_2 DIV_{it}}{P_{it-1}} \right) = \beta_2 \left( \frac{EPS_{it}}{P_{it-1}} \right) + \beta_1 \left( \frac{\Delta EPS_{it}}{P_{it-1}} \right) + \bar{\epsilon}_{it} \quad (7) \]
Since buy and hold return exclusive of dividends is commonly employed in the literature to measure stock returns (Kothari & Zimmerman 1995), we exclude dividends from equation (7).\textsuperscript{118} The resulting model is identical to the Easton & Harris (1991) expect that net return is used instead of gross return as the dependent variable, econometrically this has no effect on estimates of the earnings response coefficients\textsuperscript{119}.

4.2 Return Model

Due to the aforementioned shortcomings of the Price model, the Easton and Harris (1991) return model is commonly employed alongside the Price model in the literature. As derived earlier, the Easton and Harris (1991) return model uses a regression of stock returns on earnings yield (reciprocal of P/E ratio) and changes in earnings yield to measure the explanatory power of accounting information.

\[
\text{Model II:} \left( \frac{P_t - P_{t-1}}{P_{t-1}} \right) = \gamma_1 \left( \frac{EPS_t}{P_{t-1}} \right) + \gamma_2 \left( \frac{\Delta EPS_t}{P_{t-1}} \right) + \varepsilon_t
\]

However, stock returns in a given period reflect only the unexpected (surprise) component of the current period’s earnings growth and news that cause the market to revise expectations about future earnings growth. In reality, neither the unexpected growth in current period earnings nor the revisions in market expectations about future earnings are observed in a given period (Collins et al. 1994). A researcher can only

\textsuperscript{118} In the context of our derivation, excluding dividend yields is necessary to ensure that the OLS estimates of the model parameters are identified.

\textsuperscript{119} Using net return as opposed to gross return has no effect on the ERCs because \( \gamma_{OLS} = \frac{\text{Cov}(r, EPS)}{\text{Var}(EPS)} \), statistically this is equivalent to \( \frac{\text{Cov}(1 + r, EPS)}{\text{Var}(EPS)} \) because \( \text{Cov}(1 + r, EPS) = \text{Cov}(r, EPS) \).
observe actual earnings and changes in actual earnings that comprise of both the expected and unexpected parts of earnings. The inability to differentiate between the value-irrelevant expected earnings growth and the value-relevant unexpected earnings growth leads to the classical measurement error problem, resulting in an attenuation bias on the earnings response coefficient. Nonetheless, unlike price models the direction of this bias is known with certainty in a return model. Therefore, a researcher can establish a lower bound on the value relevance of accounting information and draw conservative inferences about the relationship between stock prices and accounting information.

Table 12 Return Model Regressions

<table>
<thead>
<tr>
<th></th>
<th>$\alpha_1$</th>
<th>$\gamma_1$</th>
<th>$\gamma_2$</th>
<th>R-square</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled OLS Model:</td>
<td>0.113***</td>
<td>0.215***</td>
<td>0.182***</td>
<td>9.62</td>
<td>1160</td>
</tr>
<tr>
<td></td>
<td>(0.016)</td>
<td>(0.031)</td>
<td>(0.037)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fixed Effects Model:</td>
<td>-0.045</td>
<td>0.230***</td>
<td>0.160***</td>
<td>35.48</td>
<td>1160</td>
</tr>
<tr>
<td></td>
<td>(0.143)</td>
<td>(0.039)</td>
<td>(0.038)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$r_{it}$ = Annual buy & hold rate of return (excluding dividends) of firm i in period t, i.e., $r_{it} = \frac{P_{it}-P_{it-1}}{P_{it-1}}$, $x_{it}$ represents the earnings yield of firm i in period t, $x_{it} = \frac{\text{EPS}_{it}}{r_{it-1}}$, similarly changes in earnings yield of firm i in period t are $\Delta x_{it} = \frac{\text{EPS}_{it}-\text{EPS}_{it-1}}{P_{it-1}}$. $\delta_t$ captures the time-related shocks across firms in a given year and $\mu_i$ accounts for the time-invariant, firm-specific effects, $\varepsilon_{it}$ is white noise. Standard errors provided in the parenthesis below parameter estimates. Asterisks indicate statistical significance, where ***, **, * represent significance at 1%, 5% and 10% respectively.

120Beaver et al. (1997) provide a list of instrumental variables commonly used to mitigate the measurement error problem in the value relevance literature, they find that none functions as a clean instrumental variable.
We use both pooled OLS and two-way fixed effects to estimate this return model. Data was winsorized at the top and bottom 1.5% to exclude outliers and Newey-West standard errors were used to account for autocorrelation in the error term structure\textsuperscript{121}. As expected, the regression results in Table 12 show that the explanatory power of accounting information vis-à-vis stock returns is significantly reduced after controlling for scale effects in the Price model. Nonetheless, both earnings yield and changes in earnings yield are positive and statistically significant at the 1% level, the coefficient estimates are robust to estimation method. Intuitively, coefficient on earnings yield ($y_1$) is a proxy for market’s expectation about a firm’s future cash flows while the coefficient on changes in earnings yield ($y_2$) serves as a noisy proxy for changes in stock return due to revisions in the market’s expectation about future earnings (Collins et al. 1994). The results from the corresponding time series regressions (not reported for the sake of brevity) reveal a decline in the explanatory power of earnings, an issue that we address in Section 6.

The R-square of 9.62% from the pooled OLS model can be used to compare the explanatory power of accounting information in the KSE with other studies that use the Easton & Harris (1991) model. Easton et al. (1994) report an R-square of 7% in the US and Germany using data on 230 listed firms from 1982-1991. Similarly, Chen. et al. (2000) observes an R-square of 11% in the Chinese stock market and Filip and

\textsuperscript{121}We excluded dividend yield from buy and hold stock returns since reliable data on dividends over the sample period was available for less than 30% of the firms in the dataset, no meaningful differences were observed between estimates based on this subset of the data and the final results.

4.3 Summary of Results

To summarize, we critically examined and estimated the econometric models commonly used to examine the relationship between stock prices and firm specific information embedded in annual financial statements. The empirical results presented in this Section clearly document a nontrivial relationship between stock prices and firm fundamentals in the KSE, robust to different econometric specifications and estimation methodologies.

Our empirical results show that the effect of trade based manipulation on the growth of KSE was greatly exaggerated. These findings warrant a reconsideration of the hypothesis that KSE is a “phantom” stock market (Khawaja and Mian 2003; Azad et al. 2014) devoid of economic reality. From an economic theory perspective, several developments support our conclusion. First, concrete plans of cross border listing and a demutualized exchange in KSE undermine the incentives necessary to sustain the theory of systematic collusion among large brokers. Because increases in stock market capitalization along with broad based investor participation reduce the influence of dominant, incumbent brokers on stock prices. Given that, trade based manipulation is an exercise of market power, it becomes less pervasive as the market opens up. Second, in capital markets
collusion among brokers in equilibrium requires very strong disincentives to inhibit cheating or defection. Goods market pricing models based on collusion have failed to explain the policies of OPEC (Smith 2005), a setting where the disincentives from cheating are much stronger. Lastly, the naive positive-feedback investment strategy (a central part of Khawaja and Mian 2005) is difficult to justify over a long horizon. Since, investor’s beliefs about the growth of stock market driven by trade based manipulation will eventually correct over time and lack of investment will lead to a decline in the stock market rather than the observed exponential growth.

5 Further Analyses

In order to further understand the relationship between stock prices and accounting information we analyze the information content of accounting losses and the effect of firm size on stock returns in this Section.

5.1 Controlling for Losses

Negative earnings, transitory earnings and non-recurring items can adversely affect the relationship between stock prices and earnings (Collins et al. 1997). Basu (1997) finds that since profits tend to persist whereas losses are transitory, earnings response coefficients are higher for positive earnings than for negative earnings. Similarly, Hayn (1995) shows that because shareholders hold a liquidation/abandonment option, the informativeness of losses with respect to future cash flows is limited, hence, pooling profit and loss observations results in a downward bias on the information content of
reported earnings. To take into account this non-linear relationship between stock prices and earnings, we allow for different coefficients on positive and negative earnings by using a dummy variable to control for losses.

Table 13 Fixed Effect Regression Models with Controls for Losses

<table>
<thead>
<tr>
<th>Price Model: ( \alpha_0 + \beta_1 (1 - D)EPS_{it} + \beta_1' (1 - D)EPS_{it} + \beta_2 (1 - D)BVPS_{it} + \beta_2' BVPS_{it} + \delta_t + \mu_i + \epsilon_{it} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>FE</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Return Model: ( r_{it} = \alpha_1 + \gamma_1 (1 - D)x_{it} + \gamma_1' (1 - D)x_{it} + \gamma_2 \Delta x_{it} + \delta_t + \mu_i + \epsilon_{it} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>FE</td>
</tr>
<tr>
<td>---</td>
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<tr>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

The model is estimated using two-way fixed effects to control for time invariant firm specific factors and time varying shocks. \( D \) is a dummy variable that equals 1 if company reported a loss in the period \( t \) and 0 otherwise. Losses comprised approximately 15% of the sample data. All other variables are as defined earlier (see table 1 and table 2). Standard errors provided in the parenthesis below the parameter estimates. Asterisks indicate statistical significance, where ***, **, * represent significance at 1%, 5% and 10% respectively.

The empirical estimates in Table 13 reaffirm the hypothesized non-linear relationship between stock prices and earnings. The earnings response coefficient on negative earnings is statistically insignificant in both the Price and Return models while the earnings response coefficient on profits is statistically significant and higher compared to the earlier specifications that do not control for losses. For instance, the earnings response coefficient in the return model (\( \gamma_1' \)) rises to 0.818 in Table 13 from 0.230 in the baseline.
fixed effects model estimated in Table 12. Likewise the R-square, also increases across both the Price and Return models.

The results of the Price model also show that book value per share is significantly and positively related to the stock price of firms reporting losses while only marginally significant for firms reporting profits. More importantly, there is a clear shift in explanatory power from earnings to book values in the case of negative earnings. The earnings response coefficient for firms reporting profit ($\beta_1$) is positive and significant at the 1% level while the earning response coefficient for firms operating losses ($\bar{\beta}_1$) is statistically insignificant. Likewise, the coefficient on book value per share for firms reporting losses ($\bar{\beta}_2$) is 1.02 compared to only 0.140 for firms operating profits ($\beta_2$), and while $\bar{\beta}_2$ is statically significant at the 1% level, $\beta_2$ is only marginally significant. These observations can be understood in view of the work of Collins et al. (1999) and Berger et al. (1996), who show that book value per share serves as a proxy for the value of the abandonment option on a firm’s stock and investors focus on balance sheet information (book value per share) in the case of negative earnings to assess their liquidation value. Consequently, book values display a relatively stronger association with stock prices when firms are making losses.

5.2 Effect of Firm Size

Though stock risks are multidimensional, Fama & French (1992), show that firm size serves as an effective proxy of firm specific risk and does a good job in explaining
returns on NYSE, AMEX and NASDAQ stocks for the 1963-1990 period. Subsequent work (Fama & French 1993) also documents a negative relationship between firm size and stock returns. The underlying logic is straightforward, smaller firms are relatively riskier investments compared to larger firms, thus in equilibrium returns on smaller firms are higher compared to larger firms. Since, the objective of this paper is to analyze the relationship between stock returns and firm specific information embedded in financial statements, book value of total assets is used to account for firm size instead of Fama & French’s (1992; 1993) measure of market capitalization. Book value of total assets and market capitalization both measure firm size, but while the former is derived directly from financial statements, market capitalization is based on the stock market. Therefore, book value of total assets is a less noisy proxy of firm size in emerging stock markets, which are generally viewed as volatile.

Table 14 reports the results of the specification with the controls for losses and firm size. As predicted by economic theory, the effect of firm size on stock returns is statistically significant at the 1% level and negative in both the pooled and fixed effects model. The R-square of 17.1% in the pooled OLS model, shows that the explanatory power of accounting information vis-à-vis stock returns approximately doubles after controlling for losses and firm size, compared to the baseline model estimated in Table 12 (R-square 9.6%). Apart from an increase in R-square, no other noteworthy changes are observed in the coefficient estimates. Next, we exploit the relatively long panel dataset, to examine changes in the value relevance of financial statements over time.
Table 14 Return Model Regression Results with Controls for Losses & Firm Size

*Model:* \( r_{it} = \alpha_1 + \gamma_1(1 - D)x_{it} + \gamma_1 D x_{it} + \gamma_2 \Delta x_{it} + \pi \ln A_{it} + \varepsilon_{it} \)

<table>
<thead>
<tr>
<th>Model</th>
<th>( \alpha_1 )</th>
<th>( \gamma_1 )</th>
<th>( \gamma_2 )</th>
<th>( \pi )</th>
<th>R-square</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>OLS</td>
<td>0.201**</td>
<td>0.702***</td>
<td>-0.003</td>
<td>0.104***</td>
<td>0.025***</td>
<td>17.09</td>
</tr>
<tr>
<td></td>
<td>(0.083)</td>
<td>(0.060)</td>
<td>(0.038)</td>
<td>(0.037)</td>
<td>(0.009)</td>
<td></td>
</tr>
<tr>
<td>FE</td>
<td>0.693*</td>
<td>0.805***</td>
<td>-0.075</td>
<td>0.112***</td>
<td>0.103***</td>
<td>43.32</td>
</tr>
<tr>
<td></td>
<td>(0.373)</td>
<td>(0.063)</td>
<td>(0.045)</td>
<td>(0.036)</td>
<td>(0.037)</td>
<td></td>
</tr>
</tbody>
</table>

D is a dummy variable that equals 1 if company operated a loss in the current period and 0 otherwise. \( \ln A_{it} \) is the natural logarithm of firm i’s total assets in period t. All other variables are as defined earlier. T-values provided in the parenthesis below the parameter estimates. Asterisks indicate statistical significance, where ***, **, * represent significance at 1%, 5% and 10% respectively.

6 Changes in the Value Relevance of Financial Statements

From financial economics theory, we know that stock returns are a function of current and expected future earnings growth rates, hence regression of stock return on earnings growth rates is another popular specification of the return model (Kothari 2001).\(^{122}\) In order to examine changes in the value relevance of financial statements we estimate the following model using both pooled OLS and year by year (time series) regressions\(^{123}\):

\[ r_{it} = \alpha_1 + \theta X_{it} + \varepsilon_{it} \]

The earnings response coefficient and R-square in the pooled OLS model are similar to their counter parts from the Easton & Harris (1991) model reported in Table 12.

\(^{122}\)Nonetheless, like all return model this specification also suffers from attenuation bias.

\(^{123}\)Following the literature if earnings were negative in the denominator, the absolute value of earnings was used.
Table 15 Return Model Year by Year Regressions

\[ r_{it} = \alpha_1 + \theta X_{it} + \epsilon_{it} \]

<table>
<thead>
<tr>
<th>Year</th>
<th>(\alpha_1)</th>
<th>(\theta)</th>
<th>R-square</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled</td>
<td>0.145***</td>
<td>0.215***</td>
<td>12.63</td>
<td>1140</td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td>(0.017)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 1999</td>
<td>0.090</td>
<td>0.176***</td>
<td>9.29</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>(0.068)</td>
<td>(0.057)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2000</td>
<td>0.036</td>
<td>0.298***</td>
<td>19.44</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>(0.064)</td>
<td>(0.063)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2001</td>
<td>0.303***</td>
<td>0.507***</td>
<td>32.34</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>(0.085)</td>
<td>(0.076)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2002</td>
<td>0.792***</td>
<td>0.391***</td>
<td>29.64</td>
<td>99</td>
</tr>
<tr>
<td></td>
<td>(0.078)</td>
<td>(0.052)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2003</td>
<td>0.334***</td>
<td>0.268***</td>
<td>13.83</td>
<td>96</td>
</tr>
<tr>
<td></td>
<td>(0.067)</td>
<td>(0.069)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2004</td>
<td>0.178***</td>
<td>0.136***</td>
<td>8.63</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>(0.054)</td>
<td>(0.045)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2005</td>
<td>0.053</td>
<td>0.165***</td>
<td>14.08</td>
<td>98</td>
</tr>
<tr>
<td></td>
<td>(0.035)</td>
<td>(0.042)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2006</td>
<td>0.297***</td>
<td>0.247***</td>
<td>15.23</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>(0.055)</td>
<td>(0.062)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2007</td>
<td>-0.90***</td>
<td>0.075**</td>
<td>4.92</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>(0.043)</td>
<td>(0.035)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2008</td>
<td>-0.061</td>
<td>0.061</td>
<td>2.52</td>
<td>92</td>
</tr>
<tr>
<td></td>
<td>(0.047)</td>
<td>(0.039)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2009</td>
<td>-0.111**</td>
<td>0.118***</td>
<td>10.39</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td>(0.052)</td>
<td>(0.036)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year 2010</td>
<td>0.045</td>
<td>-0.0035</td>
<td>0.00</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>(0.046)</td>
<td>(0.037)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(r_{it}\): Annual buy and hold net stock return excluding dividend yield, prices 3 months after the end of financial year used to calculate return. \(X_{it} = \frac{\text{Earnings}_{t} - \text{Earnings}_{t-1}}{\text{Earnings}_{t-1}}\), net earnings growth rate in period t, calculated as the annual growth in earnings per share before tax in a financial year. Standard errors provided in the parenthesis below the parameter estimates. Asterisks indicate statistical significance where ***, **, * represent significance at 1%, 5% and 10% respectively.

However, the year by year regressions reveal that the association between accounting information and stock returns has declined over time. The value relevance of financial
statements increased significantly between 1999-2002 most likely due to the formation of SECP and implementation of capital market reforms in 1999 and 2002 respectively. Thereafter, it declined steadily especially during 2008 and 2010. In light of the conceptual framework of stock prices changes introduced in Section 3, we can conclude that changes in the value relevance of accounting can arise due to changes in the properties of accounting information, relative abundance & quality of non-accounting information and level of noise. We discuss each category separately in this Section along with their relative bearing on the explanatory power of accounting information vis-à-vis stocks in the KSE.

As highlighted in the conceptual framework, earnings properties are an important determinant of the value relevance of financial statements. More importantly, unlike noise, earnings properties are relatively easier to measure and analyze. Therefore, in this Section we investigate three different properties of accounting earnings that may have led to the observed decline in the explanatory power of accounting information, i.e., earnings persistence, earnings predictability and lastly earnings lack of timeliness.

6.1 Earnings Quality

Stock valuation models are either based on discounted future cash flows or price-earnings multiples, evidently earnings levels are a key input in both types of models. However, in addition to earning levels, empirical research has shown that not all changes in earnings are priced uniformly by the market (Lipe 1990; Basu 1997; and Dechowetal. 2010). For
example negative earnings, volatile earnings, or increases in earnings that are accompanied by high accruals are perceived by investors as “low-quality”, lowering the price impact of earnings announcements. The underlying logic straightforward: low-quality earnings are a biased measure of current firm performance and hence a poor indicator of unobserved future cash flows. Consequently, low-quality earnings are viewed by the market as transitory and receive less weightage in valuation models, resulting in a lower association between changes in stock prices and accounting information.

All else equal, the relationship between stock prices and accounting information is dependent upon the both the ability of financial statements to accurately capture firm performance and the prevalent financial reporting environment in a given country. Therefore, an observed decline in the value relevance of financial statements could be driven by a decline in the average quality of accounting earnings or changes in the institutional environment.

6.1.1 Accounting Measures of Earnings Quality-Persistence and Predictability

Measures of earnings quality are classified into two groups: accounting-based attributes and market-based attributes, the former relies on only accounting information while the later is based on accounting and market information. Given our focus changes in properties of accounting information over time, we focus on two widely used accounting based measures of earnings quality, i.e., earnings persistence and earnings predictability.
This choice is supported by the accounting literature, which shows that earnings persistence and predictability are key determinants of changes in the value relevance of financial statements (Kormendi & Lipe 1987; Lipe 1990; Ramakrishnan & Thomas 1998 and Cahan et al. 2009). For example Lipe (1990) finds that ERCs estimated from standard value relevance regressions are an increasing function of earnings persistence and predictability, i.e., high (low) earnings persistence and predictability is associated with high (low) value relevance of financial statements. Thus, a decline in average earnings persistence & predictability over time may lead to lower value relevance of accounting information.124

The rationale behind the impact of earnings persistence and predictability on value relevance of financial statements is simple; earnings comprise of a permanent component directly related to firm fundamentals, a transitory component related to earnings management (smoothing or manipulation) and noise arising from shocks. Changes in earnings in a given period, attributable to the transitory component or noise are temporary and unrelated to long term firm performance (low quality earnings), while changes due to the permanent component are expected to continue into the future and representative of long term firm performance (high quality earnings). Therefore, the former is not an appropriate measure of the company’s intrinsic value and thus receives a weak stock price response, lowering the contemporaneous relationship between earnings and stock

124 Even within a country, many external factors can lead to synchronous changes in aggregate earnings quality over time for example macroeconomic shocks, stock market liberalization, changes in the financial reporting or competitive environment, distribution of stock ownership and industry trends etc can incentivize earnings manipulation or smoothing by the management in a bid to conceal actual firm performance.
returns (Dechow et al. 2010), while changes in earnings due to the permanent component solicit a strong valuation from the market since they are indicative of future cash flows. Econometrically, if the earnings time series comprises largely of the transitory component or noise, one would observe large year to year variations in earnings (low persistence) and a poor fit of a autoregressive model (low predictability). In order to test this empirically, we employ the following standard models (Lipe 1990, Dechow et al. 2010 and Gaio & Raposo 2011) to capture earning persistence and predictability:

\[
\text{Model III:} \begin{cases} 
\text{EPS}_{it} = \alpha + \rho \text{EPS}_{it-1} + \mu_{it} \\
\hat{\sigma}_t = \sqrt{\frac{\sum_{t=1}^{N} (\hat{\epsilon}_t - \bar{\epsilon})^2}{N-1}} \end{cases}
\]

In Model III, the coefficient $\rho$ measures earnings persistence. A positive and statistically significant value close to 1 would show that earnings are high quality (on average) and changes in earnings are primarily driven by the permanent component of earnings. Likewise, $\hat{\sigma}$ is a proxy for earnings predictability and measures variations in earnings changes due to the transitory earnings components or noise. In order to standardize this proxy for year to year comparisons, we scale $\hat{\sigma}$ by the cross-sectional mean of earnings to control for any trends in the earnings over time. Lower values of $\hat{\sigma}$ are indicative of high quality earnings. Some researchers employ R-square from Model III to proxy for earnings predictability and in that case a high R-square would indicate high quality earnings (Cahan 2009).
Before presenting the results we reiterate our estimation approach. Most researchers (Harris et al. 1994; Sloan 1996; Xie 2001 & Hanlon 2005) use cross-sectional analysis to estimate parameters in different empirical analogues of earnings quality models in country level studies. Whereby, firm-year observations within a year are pooled to estimate a single parameter, representing the average level of earnings quality in a given year. This allows researchers to digress from intra firm heterogeneity and focus on the average level of earnings quality prevailing in a given stock market based on different proxies of earnings quality.

Another practical advantage of the cross-sectional approach is the reliability of parameter estimates due to a large estimation sample unlike firm-level estimates which are usually based on only 10-15 time series observations\textsuperscript{125}. Nonetheless, depending on the research question and data set, many researchers have effectively contributed to the value relevance literature by employing firm level estimates based on time-series data (Cahan et al. 2009 and Gaio & Raposo 2011). However, given the nature of our research question, i.e., understanding the stock market wide, aggregate impact of accounting information on stock returns over time in the KSE, following (Sloan 1996 and Dechow and Schrand 2004) we digress from firm level differences in measures of earning quality and limit our analysis to cross-sectional estimation methods.

\textsuperscript{125}For many emerging/frontier markets reliable data for 10-15 years is generally not available, limiting the usefulness of firm level estimates based on time series data.
Table 16 Earnings Quality-Estimates of Earnings Persistence & Smoothness

Model: \( EPS_{it} = \alpha + \rho EPS_{it-1} + \epsilon_{it} \)

\[
\hat{\sigma}_t = \sqrt{\frac{\sum_{i=1}^{N}(\epsilon_{it} - \bar{\epsilon}_t)^2}{N - 1}} \]

<table>
<thead>
<tr>
<th>Year</th>
<th>( \alpha )</th>
<th>( \rho )</th>
<th>( R )-square</th>
<th>( N )</th>
<th>t-test ( \rho = 1 )</th>
<th>( EPS_t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>0.57</td>
<td>1.44***</td>
<td>0.740</td>
<td>92</td>
<td>3.71*</td>
<td>12.75</td>
</tr>
<tr>
<td></td>
<td>(1.45)</td>
<td>(0.22)</td>
<td></td>
<td></td>
<td>(1.45)</td>
<td></td>
</tr>
<tr>
<td>2001</td>
<td>3.36</td>
<td>0.78***</td>
<td>1.794</td>
<td>99</td>
<td>2.93*</td>
<td>12.52</td>
</tr>
<tr>
<td></td>
<td>(3.11)</td>
<td>(0.13)</td>
<td></td>
<td></td>
<td>(0.22)</td>
<td></td>
</tr>
<tr>
<td>2002</td>
<td>1.242</td>
<td>1.11***</td>
<td>0.794</td>
<td>99</td>
<td>0.91</td>
<td>15.22</td>
</tr>
<tr>
<td></td>
<td>(1.23)</td>
<td>(0.12)</td>
<td></td>
<td></td>
<td>(0.13)</td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td>1.77</td>
<td>1.15***</td>
<td>0.602</td>
<td>96</td>
<td>0.93</td>
<td>19.95</td>
</tr>
<tr>
<td></td>
<td>(1.78)</td>
<td>(0.16)</td>
<td></td>
<td></td>
<td>(0.16)</td>
<td></td>
</tr>
<tr>
<td>2004</td>
<td>7.01</td>
<td>0.66*</td>
<td>0.814</td>
<td>97</td>
<td>0.89</td>
<td>20.40</td>
</tr>
<tr>
<td></td>
<td>(5.19)</td>
<td>(0.36)</td>
<td></td>
<td></td>
<td>(0.36)</td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>3.22</td>
<td>1.04***</td>
<td>0.765</td>
<td>100</td>
<td>0.03</td>
<td>23.78</td>
</tr>
<tr>
<td></td>
<td>(3.28)</td>
<td>(0.24)</td>
<td></td>
<td></td>
<td>(0.24)</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td>0.410</td>
<td>1.11***</td>
<td>0.465</td>
<td>96</td>
<td>3.22*</td>
<td>28.05</td>
</tr>
<tr>
<td></td>
<td>(1.49)</td>
<td>(0.07)</td>
<td></td>
<td></td>
<td>(0.07)</td>
<td></td>
</tr>
<tr>
<td>2007</td>
<td>0.50</td>
<td>1.01***</td>
<td>0.658</td>
<td>96</td>
<td>0.02</td>
<td>27.59</td>
</tr>
<tr>
<td></td>
<td>(2.06)</td>
<td>(0.08)</td>
<td></td>
<td></td>
<td>(0.08)</td>
<td></td>
</tr>
<tr>
<td>2008</td>
<td>1.31</td>
<td>1.03***</td>
<td>0.995</td>
<td>92</td>
<td>0.03</td>
<td>27.25</td>
</tr>
<tr>
<td></td>
<td>(3.76)</td>
<td>(0.19)</td>
<td></td>
<td></td>
<td>(0.19)</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td>-0.17</td>
<td>0.825***</td>
<td>1.479</td>
<td>95</td>
<td>1.21</td>
<td>20.58</td>
</tr>
<tr>
<td></td>
<td>(2.28)</td>
<td>(0.16)</td>
<td></td>
<td></td>
<td>(0.16)</td>
<td></td>
</tr>
<tr>
<td>2010</td>
<td>9.61***</td>
<td>0.976***</td>
<td>0.969</td>
<td>95</td>
<td>0.03</td>
<td>28.95</td>
</tr>
<tr>
<td></td>
<td>(3.57)</td>
<td>(0.13)</td>
<td></td>
<td></td>
<td>(0.13)</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>1.46</td>
<td>1.22***</td>
<td>0.784</td>
<td>91</td>
<td>9.23***</td>
<td>36.55</td>
</tr>
<tr>
<td></td>
<td>(2.42)</td>
<td>(0.07)</td>
<td></td>
<td></td>
<td>(0.07)</td>
<td></td>
</tr>
</tbody>
</table>

EPS represents earnings per share before tax. Standard errors are provided in the parenthesis below the parameter estimates. Asterisks indicate statistical significance, where ***\*, **, * represent significance at 1%, 5% and 10% respectively. We lose one year at the beginning of the sample (1999) due to the lag structure of the estimated model.

Table 16 shows that though earnings per share depicted a positive trend on average but a decline between 2006-2009, especially after the 2008 financial crisis is evident. The
estimation results also reveal that earnings were highly persistent throughout this period as $\rho$ is statistically significant, positive and close to 1, and the null hypothesis that $\rho = 1$ (perfectly persistent earnings) can only be rejected in 4 out of the 12 years. This suggests that the earnings series was smooth and changes in earnings were primarily driven by the permanent component of earnings, resulting in high quality earnings. Nonetheless, the magnitude of $\rho$ has declined slightly over time. Likewise, earnings predictability has also shown a marginal decline, given that $\sigma$ increased and the R-square of the earnings persistence model decreased during this period, especially between 2006-2009.

The estimated results from both measures of earnings quality, i.e., persistence and predictability show a marginal decline. Qualitatively, it seems difficult to attribute the sharp decline in the explanatory power of accounting information in the KSE to deterioration in earnings quality alone, especially since both measures of earnings quality improve post 2009. We return to questions about the quantitative impact of earnings quality on the value relevance of accounting information at the end of Section 7.

Before examining the prices lead earnings or the earnings lack of timeliness hypothesis as a determinant of the observed decline in the explanatory power of accounting information in the KSE we analyze the institutional environment of KSE to determine its impact on the value relevance of accounting information.
6.3 **Institutional Environment**

As far as the accounting institutional environment in Pakistan is concerned, there was no significant change in the financial reporting environment that may have adversely affected the value relevance of accounting information. On the contrary, several developments suggest a gradual improvement e.g. the mandatory adoption of International Financial Reporting Standards in 2002. Likewise, Big-4 accounting firms maintained a strong presence in Pakistan throughout the period of study and approximately 65% of the firms in our sample were audited by one of the Big-4 accounting firms.\(^\text{126}\) Lastly, based on World Bank’s Corporate Governance Country Assessments of Pakistan from 1999 to 2012, one can observe a gradual improvement in the financial & regulatory reporting environment.

6.3.1. **Relative Accessibility and Quality of Non-Accounting Information on Firm Fundamentals**

Despite the importance of financial statement analysis in valuation models, financial statements are not a particularly timely source of information. The rapid development of the financial industry over the past decade has heralded the rise of stock market information intermediaries (financial press, analysts, mutual funds, brokers etc.), responsible for aggregation, analysis and certification of information on firm fundamentals, collected from different public and private sources of data. The

\(^\text{126}\) Teoh and Wong (1993) find that all else equal, higher audit quality provides greater credibility to the financial statements, consequently, on a greater percentage of audits by top audit firms lead to on average higher value relevance of financial statements in a given stock market.
information provided by information intermediaries often preempts information embedded in financial statements, which are prepared annually (or at best quarterly) under a set of strict rules, consequently weakening the contemporaneous relationship between stock returns and accounting information. Therefore, despite “high-quality” accounting information, the value relevance of financial statement may decline due to an increase in the relative availability and quality of more timely sources of non-accounting information provided by stock market information intermediaries. This may lead to the phenomenon commonly known as “prices lead earnings” or the related “earnings lack of timeliness” hypothesis, a detailed discussion of this phenomenon is provided in the next Section.

Though difficult to quantify, economic theory suggests that the emergence of information intermediaries and resulting non-accounting information flows is correlated with the size, growth and development of the stock market vis-à-vis the overall economy. As a result, institutional changes that lead to the sufficient provision of timely, high quality non-accounting information are more likely to materialize in developed countries with large, stable, lucrative financial sectors. Therefore, in countries with small, under developed stock markets, non-accounting information about firm fundamentals is expected play a limited role in driving stock returns, due to the dearth of sufficient information intermediaries. The empirical literature supports this view and highlights the key role of accounting information vis-à-vis stocks in several emerging stock markets e.g. China (Lam et al. 2013), Egypt (Ragab & Omran 2006), Greece (Maditinos et al. 2013),
Tunisia (Naceur & Goaied 2004), Turkey (Anandarajan et al. 2006) and Pakistan (Chaudhry & Sam 2014) compared to developed markets, despite market imperfections and weaknesses in the regulatory environment in developing countries. On the other hand, the pervasiveness of information intermediaries in countries like US, Japan & Germany, is a key factor behind the low explanatory power of accounting information (usually less than 10%) vis-à-vis cross-sectional stock returns (Harris et al. 1994 and Kothari 2001). This is an important observation, given the fact that corporate governance and financial reporting environment is stronger in developed countries leading to relatively higher-quality earnings compared to less developed countries.

In the specific case of Pakistan, the stock market information intermediation industry is underdeveloped, even by developing country standards. For instance, DeFond et al. (2007) show that the mean number of forecasts per firm in Pakistan is very low relative to other regional stock markets and the dispersion in earnings forecasts is also much higher in Pakistan compared to similar stock markets. Both observations point towards an underdeveloped information intermediation sector. Pakistan’s fundamentally bank oriented financial system (as opposed to a stock market oriented financial system) is another important factor behind the limited the growth of stock market intermediaries, whereby firms prefer to finance projects through bank loans rather than through stock market issues and similarly investors prefer to deposit surplus wealth in banks over

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127 In their research the mean number of forecasts per firm varied from a low of 3.24 in Pakistan to 9.23 in Philippines, 10.67 in Malaysia, and 13.32 in Australia. Similarly, the mean forecast dispersion in Pakistan is significantly higher to that of India, Malaysia and Australia.
investment in stock market. Naturally, this limits the demand for services provided by stock intermediaries. Anecdotal evidence also suggests that despite the exponential growth of KSE, there was no dramatic decline in the relative scarcity of reliable non-accounting information that may have potentially weakened the contemporaneous relationship between accounting information and stock returns.

The abovementioned stylized facts allow us to rule out improvements in accessibility and quality in alternative sources of non-accounting information as a valid explanation for the decline in the value relevance of financial statements in the KSE.

6.4 Earnings Lack of timeliness Hypothesis

Collins et al. (1994) explain that earnings lack of timeliness vis-à-vis stock return implies that some of the information in current earnings is already impounded in the past prices and thereby unrelated to the current stock returns, consequently weakening the contemporaneous association between current earnings and returns. Likewise, Kothari and Sloan (1992) show that stock returns are expected to lead changes in earnings because stock returns over a period reflect the market’s revision of future expected earnings and are based on “forward-looking” information. While, accounting earnings over the same period, prepared under the notions of conservatism, prudence and historical cost are “backward looking” and thus cannot reflect revised expectations about future earnings. Thus, under the prices lead earnings hypothesis earnings incorporate the information reflected in price changes with lags (Kothari 1992). This effect may become
more prominent over time, given the fact that as emerging stock markets develop, prices tend to impound more and more information about future earnings, i.e., prices become forward looking. Therefore, earnings lack of timeliness/prices lead earnings can lead to a reduction in the contemporaneous explanatory power of accounting information.

The econometric consequence of earnings lack of timeliness is that stock returns of a given time period are related to earnings growth rates of contemporaneous and future time periods. In order to evaluate the strength of the earnings lack of timeliness hypothesis, we follow the approach of Collins et al. (1994) and estimate the following model:\textsuperscript{128}

\textbf{Model IV:} \( R_{it} = \alpha + \beta_1 X_{it} + \sum_{t=1}^{L} \beta_{t+1} X_{it+1} + \sum_{t=1}^{L} \beta_{t+L+1} R_{it+1} + \epsilon_{it} \)

Collins et al. (1994) show that a statistically significant, positive coefficient on earnings growth leads will lend support to the lack of earning timeliness hypothesis. They also illustrate that inclusion of stock return leads mitigates the measurement error problem inherent to return models and its coefficient is expected to be negative\textsuperscript{129}.

\textsuperscript{128} Their original specification included growth in investment and lagged earnings yield as additional proxies for measurement errors in the model, however coefficients on both variables were found to be statistically insignificant in our case. Therefore we don’t include them in our model.

\textsuperscript{129} They argue that the coefficient on stock return leads is expected to be negative in order to ensure “that irrelevant components positively related to future returns are removed from \( X_{t+k} \), leaving a better approximation to the changes in expectations of future earnings growth that occurred in period t” (Collins et al. 1994 pg. 299).
In order to determine the optimal number of leads to include in the model, we use the standard F-test approach instead of Collins et al. (1994) arbitrary approach of selecting 3 leads. We progressively augmented the model with earnings growth and stock return leads, however statistically insignificant coefficients on the two-period ahead earning growth were observed regardless of the estimation method. Jindrichovska (2001) and Maditinos et al. (2013) observed similar results in the Czech Republic and Greece respectively, i.e. trivial relationship between stock returns and future earnings growth leads beyond one-period. To ensure reliable parameter estimates, we use both pooled OLS and two-way fixed effects with robust standard errors.

The earnings response coefficient and R-square in this model are similar to their counterparts the Easton & Harris (1991) model estimated in Table 12. But the statistically significant, positive coefficient on the one-period earnings growth lead, in both models lends support to the prices lead earnings/lack of earning’s timeliness hypothesis. Nonetheless, the economic significance of this effect is very limited, because, the ERC on the earnings growth lead is approximately 5-6 times smaller compared to the ERC on the contemporaneous earnings growth rate suggesting that the prices lead earnings/lack of earning’s timeliness effect is weak. This observation supports our earlier claim that due to the underdeveloped information intermediation industry in less developed countries, non-accounting information flows to play a limited role in explaining stock returns relative to accounting information flows.
Table 17 Earnings Lack of Timeliness Hypothesis

\( R_{it} = \alpha + \beta_1 X_{it} + \beta_2 X_{it+1} + \beta_3 R_{it+1} + \varepsilon_{it} \)  
(A)

<table>
<thead>
<tr>
<th></th>
<th>( \alpha )</th>
<th>( \beta_1 )</th>
<th>( \beta_2 )</th>
<th>( \beta_3 )</th>
<th>R-square</th>
<th>N</th>
<th>( \beta_2 = 0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pooled OLS</td>
<td>0.14***</td>
<td>0.245***</td>
<td>0.054***</td>
<td>-0.004</td>
<td>15.4%</td>
<td>1034</td>
<td>8.08**</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.03)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\( R_{it} = \alpha + \beta_1 X_{it} + \beta_2 X_{it+1} + \beta_3 R_{it+1} + \delta_t + \mu_t + \varepsilon_{it} \)  
(B)

<table>
<thead>
<tr>
<th></th>
<th>( \alpha )</th>
<th>( \beta_1 )</th>
<th>( \beta_2 )</th>
<th>( \beta_3 )</th>
<th>R-square</th>
<th>N</th>
<th>( \beta_2 = 0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Effects</td>
<td>-0.13</td>
<td>0.229***</td>
<td>0.08***</td>
<td>-0.208***</td>
<td>32.9%</td>
<td>1034</td>
<td>4.27***</td>
</tr>
<tr>
<td></td>
<td>(0.18)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.03)</td>
<td></td>
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</tr>
</tbody>
</table>

\( R_{it} = \) Annual buy and hold net stock return excluding dividend yield, prices 3 months after the end of financial year are used to calculate return. \( X_{it} = \) Net earnings growth rate in period t, calculated as the annual growth in earnings per share before tax in a financial year, i.e., \( X_{it} = \frac{EPS_{t+1} - EPS_t}{EPS_t} \). Standard errors are provided in the parenthesis below the parameter estimates. Asterisks indicate statistical significance, where ***, **, * represent significance at 1%, 5% and 10% respectively. Note that the estimation sample is reduced by one year for each earnings lead included in the model, as our dataset is limited to earnings growth rates till 2010 only.

As argued by Collins et al. (1994) the coefficient (\( \beta_3 \)) on future stock returns is negative and significant at the 1% level in the fixed effects model. The insignificance of \( \beta_3 \) in the pooled OLS model is most likely due to the presence of fixed effects (F-Test for No Fixed Effects=3.76*** with p-value <0.001). Also consistent with Collins et al. (1994), inclusion of stock return leads mitigates the attenuation bias due to measurement errors in the model and estimates of \( \beta_2 \) without stock return leads in the fixed effects model (not reported) were approximately 50% smaller.

The empirical estimates suggest that the lack of earnings’ timeliness may be a valid explanation for the decline of the value relevance of earnings in the KSE. Given these findings, we re-estimated the year by year regressions by including one-period ahead earnings growth and stock return leads in order to observe whether the decline in value...
relevance of financial statements was due to the prices lead earnings/earnings lack of
timeliness effect. For sake of brevity, detailed estimation results are not reported and
instead we plot the year by year adjusted R-square from the original value relevance
model and the earnings lack of timeliness model in figure 16.

Figure 16 shows the movements in the explanatory power of accounting information over
time and reveal a cyclical, wave like pattern. For example, R-square peaked in 2002
followed by a steady decline through 2003 and 2004. In 2006, R-square improved again
but only to decline in 2007 and 2008, followed by another surge in 2009 and finally
dropping in 2010. This trend suggests that stock prices deviate from fundamentals
cyclically. The markedly higher value relevance of accounting information in 2002, 2006
and 2009 indicate that these deviations are periodically reversed, consistent with prior
research on the mean reversion of asset prices (Poterba & Summers 1989 and Cecchetti et
al. 1999). It is also evident that controlling for earnings lack of timeliness does not
change the overall decline in the value relevance of financial statements, apart from a
parallel shift upwards due to the higher explanatory power of the augmented model.
Moreover, the associated trend lines (dotted lines) for both models show a remarkably
similar negative trend (statistically significant) over time. Therefore, we can conclude
that earnings lack of timeliness cannot explain the decline in the value relevance of
financial statements.
6.5 Overview of Findings

In this Section we examined some important determinants of the value relevance of accounting information to isolate the bearing of different factors on the steady decline of the value relevance of financial statements in the KSE. To summarize, we find that earnings quality, measured by the cross-sectional mean of firm level estimates of earnings persistence and predictability, remained stable during this period albeit with a negative trend. The domestic financial reporting environment improved over time. Whereas, the underdeveloped information intermediation industry in Pakistan, allowed us to rule out the impact of changes in non-accounting information flows on the value relevance of accounting information in the KSE. Lastly, though we find evidence in support of the earnings lack timeliness effect, however it cannot explain the decline of the explanatory power of accounting information over time.

Figure 16 Decline in Value Relevance of Accounting Information
7 Value Relevance of Financial Statements and Noise

In light of our conceptual framework of stock price dynamics, the abovementioned findings lead us to focus on changes in the levels of noise as an explanation for the observed decline in the explanatory power of accounting information. Financial economists agree that noise trading levels\(^{130}\) have an effect on the ability of stock prices to impound firm-specific fundamentals information. Lee (2001) explains that in the polar case where stock markets are completely dominated by noise traders, stock prices are determined exclusively by noise trading and systematically diverge from the firm fundamentals in equilibrium. These types of capital markets are often characterized by unusually high price volatility, where the price volatility is independent of new information flows about firm fundamentals. From an econometrics standpoint, excessive volatility in stock prices results in a downward bias on the R-square of value relevance regressions and in the case of extremely high price volatility, R-square approaches zero regardless of the quality of accounting information. As a result, many researchers have coined the term “quality” of stock prices to describe the ability of stock prices to impound information about firm fundamentals (Cahan et al. 2009 and Fung et al. 2010).\(^{131}\)

In general, issues related to stock price quality are tied to market microstructure. Market microstructure principally deals with the process of price formation and price discovery

\(^{130}\)Recall our definition of noise trading, i.e., trading not based on accounting or non-accounting sources of information about firm fundamentals.

\(^{131}\)High (low) “quality” of stock prices implies a high (low) correlation between stock prices and firm fundamentals, implying low (high) levels of noise in the stock prices.
in stock markets. Including for example, how this process is affected by information and transaction costs, behavioral patterns and biases of market participants, distribution of stock market participants and the broader institutional environment. Changes in the abovementioned factors over time will affect the “quality” of stock prices and thereby lead to changes in the relationship between actual stock prices and information about firm fundamentals embedded in financial statements. Hence, given all other factors are constant, a decline in value relevance of financial statement may stem from a decline in the quality of stock prices. For example, Dontoh et al. (2004) and Fung et al. (2010) show that the return-earnings relationship also reflects the informativeness of stock prices and due to the increasing level of non–information-based trading in the modern era, stock prices have deviated from fundamental values, consequently weakening the return-earnings association. The natural question then arises, which mechanism is the dominant source of noise in the KSE and more importantly how can we quantify it?

After taking into account the literature, the stylized facts associated with the growth of KSE and the broader institutional environment prevalent in Pakistan, we argue that the phenomenon of “herding” led to the decline in the “quality” of stock prices and hence the value relevance of financial statements. We present specific arguments to support our point of view in the following paragraphs.

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For example, within the framework of bounded rationality, behavioral biases in expectation formulation methods i.e., naïve and quasi-naïve expectations. Or the proportion of market participants that can be classified as institutional investors, rational investors, noise traders, arbitragers and speculators.
7.1 The Phenomenon of “Herding”

Our approach of equating herding with noise is not unprecedented in the literature. It is well known that herding causes market prices to systematically deviate from fundamentals (Banerjee 1992). DeLong et al. (1990) explicitly show that herding by investors on market sentiment, beyond what is justified by fundamentals, is an important source of noise in stock markets and may lead to asset price bubbles. Though, deviations from firm fundamentals beyond a certain threshold are periodically corrected in lieu of the standard arbitrage arguments, nevertheless herding behavior may persist in equilibrium under certain market conditions. For example, DeLong et al. (1990) and Dow & Gorton (1994) prove that if stock market participants are risk averse and have short investment horizons then deviations of prices from fundamentals persist over time. But, what triggers the so called herding behavior and what are its propagation mechanics? Herding (or convoy) behavior of investors is usually driven by “irrational exuberance” (Greenspan 1996 and Shiller 2000) after enduring periods of bullish market behavior.

This leads to an overemphasis on the current market performance and momentum investing replaces fundamental investing (Penman 2003). Excess demand created by investors eager to reap the high returns from equity investments leads to even higher returns in the short run. This attracts more investors and the cycle continues unabated, a manifestation of what behavioral economists’ term as the “bandwagon effect.” As a result, investors are falsely led to belief that increases in (unobservable) future earnings,

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133 Note, that in the presence of high uncertainty, short investment horizons and binding capital constraints the standard arbitrage arguments to correct for mispricing are typically no longer valid.

134 Empirical literature suggests that the opposite may also be true, i.e., irrational pessimism after long periods of bearish market behavior see for example Hwang & Salmon (2004).
rather than herding behavior is driving prices and thus naïvely expect current price trends to continue into the future. On the flip side, the aforementioned behavioral biases result in Bayesian rigidity, i.e., a failure to update current beliefs about stock prices given new information about firm fundamentals (Liebowitz 2005). This process eventually culminates into “information cascades”, whereby investors disregard privately held information and merely “follow” the market sentiment. Thus, the quality of stock prices is compromised because information about firm fundamentals is no longer capitalized into stock prices.

In a nutshell, herding behavior disrupts the price discovery process by preventing the aggregation of privately held information into the stock prices. Consequently, as stock prices diverge from firm fundamentals, the association between stock returns and firm specific information embedded in financial statements is weakened.

In light of the findings of the abovementioned theoretical literature, we posit that the phenomenon of herding resulted in the decline of the explanatory power of accounting information vis-à-vis stock returns in the KSE. Our hypothesis is also supported by the empirical literature. For example, Morris and Alam (2012) observed a decline in the value relevance of financial statements in the US during the “dot com” bubble and recent work by Lam et al. (2013) also suggests that value relevance of financial statements in China declined during periods of high stock market growth.
We draw attention to some specific, stylized facts related to the growth of KSE that lend support to our hypothesis. By and large, the increased likelihood of the emergence of herding behavior in KSE can be broadly traced to two categories of stylized facts, i.e., sudden surge in macroeconomic growth and the opaque information environment.

7.2 Materialization of Herding in the KSE: Stylized Facts

The stylized facts associated with the 2008 global financial crisis, revived interest in the financial instability hypothesis proposed by Minsky in 1982. He argued that during an economic boom fundamentals are often overlooked in favor of the positive market sentiment. This leads to overinvestment, followed by asset price bubbles and eventually financial disaster as the economy returns to its balanced growth path. The macroeconomic developments in Pakistan present an interesting case study of Minsky’s theory at work in an emerging market context.

Pakistan experienced a period of unprecedented growth from 2002 to 2005: GDP growth was 6.75%, total investment increased by 23.5%, and more importantly private investment increased by 38.3% and 40.5% in 2004 and 2005 respectively, surpassing all previous records. At the same time, the usually volatile exchange rate was remarkably stable at approximately 1 Pak Rs= $0.017 and interest rates hit record lows.\(^{135}\) Furthermore, in the post 2001 era, remittances and FDI increased exponentially in lieu of

\(^{135}\) All macroeconomic data was retrieved from State Bank of Pakistan website (www.sbp.org.pk)
Pakistan’s participation in the war on terror, leading to high liquidity in the economy. Unsurprisingly, the economic boom had a positive impact on the KSE.

Policy interventions provided further momentum to the KSE. First, the capital gains tax was temporarily absolved in 2002 until about 2005 to promote the stock market (Daily Times 2002). Second, spurred by the government’s privatization scheme of lucrative nationalized industries, the period from 2002 to 2005 witnessed a high number of successful IPOs that generated more than 100 Billion Pak Rs. of revenue. Third, interest rates continued to plummet and nominal government T-bill rates remained below 2% between April-2003 to April-2004 while real deposit rates were close to zero, a rare scenario for a country where interest rates are usually recorded in double digits.

Clearly, all the elements needed to encourage herding behavior and the ensuing asset price bubbles were in place. For example, as documented by Reinhard & Rogoff (2009), asset price bubbles in emerging markets are often preceded by cheap credit. Second, the abrupt surge in overall macroeconomic conditions supported “irrational exuberance” (Greenspan 1996 and Shiller 2000). High rates of return incentivized investments in stocks while low interest rates reduced the opportunity cost of these investments. As investors flocked to participate in the KSE, stock prices soared even further, providing further impetus to the herding behavior. The bandwagon effect was further reinforced by record growth in corporate earnings in 2004, when earnings of all listed firms grew on average by 26.5% (SBP Capital Market Review 2004). These developments, lead to what
Liebowitz (2005) has termed as Bayesian rigidity, i.e., a failure to update beliefs given new information on fundamentals.

However, new information on fundamentals did not justify the investors’ enthusiasm. First, the supply of credit started to dry up and the policy rate jumped to approximately 10% by end of 2007. Political instability returned and steady rise in commodity prices, especially oil, inhibited growth. By 2008, annual GDP growth had gradually slowed down to less than 1%. More importantly in our context, firm level financial performance indicators showed signs of deterioration as early as 2006. For example, based on sample averages, annual earnings growth between 2005-2008 was only 2.3% compared to 38.4% in the three year period 2002-2005. Similarly, in 2005 only 8% of the firms reported negative earnings per share, by 2008, this number had monotonically risen to 31%. Yet, spurred by the bandwagon effect, the total market capitalization in the KSE increased from 30% of GDP in 2004 to approximately 50% by end of 2007 (World Development Indicators 2012), a clear indication that information about firm fundamentals was not being capitalized into stock prices.

Several features of the institutional environment also played a critical role in the materialization and persistence of herding behavior in the KSE. For example, high information costs, uncertainty and limited participation of institutional investors increased the likelihood of herding behavior. As discussed in detail in Section 6, lack of reliable information intermediary services (financial press, financial analyst reports and
investment management services etc.) in the KSE resulted in high information gathering and processing costs for investors. Whereas, weak regulatory environment, common to less developed countries increased the likelihood of a few traders benefiting from insider information. Moreover, incomplete risk markets (lack of derivatives and futures markets) increased the risk of making the wrong “bets”. Given this opaque information environment, with high risks and information costs, one can easily use the concept of “bounded rationality” to argue that, for any given investor, merely following the market sentiment is both perfectly rational and optimal (Banarjee 1992).

The different types of investors participating in a stock market also plays a key role in determining the informativeness of prices and hence the persistence of herding behavior. In the case of limited participation of institutional investors (insurance companies, pension funds, mutual funds and banks etc.) mispricing can persist in equilibrium for several reasons. Firstly, due to economies of scope, institutional investors readily employ sophisticated analysis to determine intrinsic values of stocks before making a buy/sell decision. This has a positive effect on the overall quality of stock prices in a market. For example, Pi and Timme (1993) illustrate that institutional investors in the developed countries contribute to the efficient pricing of securities due to their sophisticated investment analyses and experience. On the other hand, individual investors usually avoid detailed analysis due to the lack of the necessary information processing skills and instead rely on market signals. Consequently, in the absence of institutional investors,
individual investors may fail to recognize a systematic divergence between prices and fundamentals, driven by herding among other mechanisms, in a timely manner.

Secondly, institutional investors usually make portfolio allocation decisions based on long investment horizons. This allows them to successfully employ contrarian strategies (selling when everyone is buying and buying when everyone is selling, the exact opposite of herding behavior), which are widely believed to mitigate equilibrium mispricing and market instability. However, as is commonly observed in less developed countries, the exponential rise of KSE attracted individual investors with short investment horizons, eager to make quick gains. As opposed to institutional investors with long horizons136. For instance, during 2006 to 2011, the average ratio of mutual fund assets to GDP in Pakistan was only 1.8% (Global Financial Database 2015). Similarly, according to Asian Development Bank Report (2006), a high volume of short-term individual investors in the KSE was a major reason for the observed stock market volatility.

It is well known that contrarian strategies cannot be employed by investors with short investment horizons because the success of contrarian strategies requires a sufficiently long investment horizon to allow for correction of mispricings as stock prices converge to their intrinsic values (DeLong et al. 1990). Besides, in contrast to institutional investors, individuals also do not have the capital to maintain long positions in distressed stocks

136 For example, Didier & Schmukler (2014) find that institutional investors in emerging markets are significantly smaller (in term of size of assets under management) in emerging markets compared to developed countries. They also report that most of assets of institutional investors in Asia, similar to emerging markets in general, are in the form of government bonds and bank deposits as opposed to corporate securities.
during prolonged periods of market stress. Therefore, in the absence of institutional investors with long horizon, systematic divergences between prices and firm fundamentals will not be quickly arbitraged away.

Lastly, DeLong et al. (1990) show that as the percentage of “trend chasers” in the markets increases, they may actually drive out the institutional investors, adding impetus to the phenomenon of herding and further deteriorating the price discovery process. DeLong et al. (1990) succinctly state “Noise traders who follow a herding strategy benefit from the risk that their own participation creates. They make risk averse informed traders less willing to participate in the market so prices are lower and returns higher, and these higher returns are more likely to be earned by the participating noise traders. This suggests a positive association between returns and the level of speculative intensity.” Their theory is highly consistent with the observed facts, i.e., KSE outperformed better known emerging markets like Brazil, India and China in terms of return and at the same time it was also relatively inexpensive (Hussain 2006).

To summarize, our narrative of herding behavior in the KSE is based on the following salient features: Initially, good macroeconomic performance and strong firm fundamentals led to high stock returns in the KSE. Abolishment of capital gains tax and cheap credit further incentivized participation in the KSE. Record earnings announcement in 2004 reinforced the “irrational exuberance” of investors and stock

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137 In DeLong et al. 1990 herding not based on information is referred to as speculation.
prices overshot due to high demand. This attracted even more investors towards the KSE and added further impetus to price inflation caused by herding. The herding phenomenon was in full swing by now; reinforced by certain institutional features of the KSE, in particular the opaque information environment and limited participation of institutional investors. As asset prices diverged from firm fundamentals, value relevance of financial statements declined because investors disregarded new information about firm fundamentals embedded in financial statements, a manifestation of Bayesian rigidity. We now turn our attention towards the empirical methods used to identify herding behavior.

7.3 Empirical Models of Herding

The increasing popularity of behavioral finance over the past decade has generated a lot of interest in herd behavior in financial markets. Nevertheless, despite the large theoretical literature on herding, the existence and persistence of herding behavior in stock markets remains primarily an empirical question. This gap has been filled by the burgeoning literature on the empirical analysis of market wide herd behavior in different stock markets. This literature initially focused on developed markets like US, UK (Christie & Huang 1995; Chang et al. 2000 and Hwang & Salmon 2004) and Italy (Caparrelli et al. 2004) etc, but emerging economies e.g. Taiwan (Demirer et al. 2010), China (Demirer & Kutan 2006), South Korea (Hwang & Salmon 2004) and Saudi Arabia (Rahman et al. 2015) have begun to increasingly attract the interest of researchers. Given the special circumstances associated with the rise of KSE and its unique institutional environment, our paper also contributes to this stream of literature.
Econometric models to identify market wide herding behavior can be divided into two categories. The return dispersion methodology originally developed by Christie & Huang (1995) and later improved by Chang et al., (2000). And the more recent, beta dispersion methodology developed by Hwang & Salmon (2004).

Christie & Huang (1995) argued that investors are more likely to suppress their private information and herd on market sentiment during periods of market stress. Their identifying assumption was that if investors herd on the market sentiment then the dispersion of individual stock returns from the market return will decrease during periods of market stress. This is in contrast to rational asset pricing models like CAPM, which predicts that during periods of market stress dispersion of individual stock returns from the market return should increase due to the different factor sensitivities of different stocks. The empirical analogue of their idea lies in first computing return dispersion as the cross-sectional mean of absolute deviations of individual stock returns from the market return. Thereafter, observations in the tails of the market return distribution are used to identify periods of extreme movements. Lastly, an OLS regression, with return dispersion as the dependent variable and dummy variables corresponding to extreme positive and negative movements in market return as independent variables, is estimated to determine whether return dispersion increased or decreased during periods of extreme market movements. A negative and statistically significant coefficient on both dummy variables lends support to herding behavior and vice versa. Later on, Chang et al., (2000)
suggested that a more robust strategy of identifying herding behavior should be based on a non-linear relationship between return dispersion and market returns as opposed to the linear model proposed by Christie & Huang (1995).

Prior to the seminal work of Hwang & Salmon (2004), the return dispersion methodology dominated the literature. However, Hwang & Salmon (2004) highlighted a key weakness of the return dispersion methodology by pointing out that the return dispersion methodology cannot differentiate between “spurious” herding, i.e., trading in the same direction due to common movements in fundamentals and “true” herding behavior, i.e., trading in the same direction in the absence of any common movements in fundamentals. Since, return dispersion models treat both types of “decision-clustering” identically thus, herding behavior cannot be separated from spurious herding, i.e., clustering of decisions due to movements in fundamentals. For example, public announcements of positive fundamentals may lead to clustering around the market return even in the absence of “true” herding behavior.

Another weakness of the return dispersion methodology, in particular the Christie & Huang (1995) approach, is the fact that it is based on the identifying assumption that herding behavior is only manifested during extreme movements in the market. This assumption may not be valid. First, a large body of theoretical literature has clearly shown that herding is a persistent phenomenon, given the appropriate environmental conditions (DeLong et al. 1990 and Banarjee 1992). Second, the manifestation of herding
behavior is driven by the effect of economic trends and institutional environment on the behavior of market participants as opposed to extreme movements in market return\textsuperscript{138}. Lastly, another drawback of the return dispersion methodology is the often arbitrary definition of extreme movements e.g. cutoffs of 1% or 5% for observations in the tails of the distribution. These drawbacks have led to a decline in the popularity of the return dispersion methodology. For a more detailed comparison of both methodologies along with their underlying assumptions and possible interpretations the interested reader is referred to the (Demirer et al. 2010).

The Hwang & Salmon (2004) state-space model is also more suitable for addressing our research question. Because, as opposed to mere existence, we are interested in the evolution of herding behavior in order to understand whether changes in herding behavior can explain the decline in the value relevance of financial statements. At the same time, given the assumption that accounting information is associated with firm fundamentals and properties of accounting information have not changed over time, we can interpret a simultaneous increase in herding behavior and a decrease in the value relevance of accounting information as empirical evidence in support of the theory that herding behavior leads to deviations of stock prices from firm fundamentals. The next subsection provides a description of the Hwang and Salmon (2004) state space model.

\textsuperscript{138}In fact, large shocks may lead to a reduction in herding behavior or “adverse” herding” as stocks converge towards fundamentals (Hwang & Salmon 2004).
7.4 Beta Dispersion Methodology: The Hwang & Salmon (2004) State Space Model

The Hwang & Salmon (2004) state-space model, based on the CAPM framework, examines the dispersion of stocks betas or factor sensitivities to market return instead of return dispersion in order to differentiate between co-movements in stock returns based on fundamental and non-fundamental factors. This approach allows them to control for movements in fundamentals and isolate true herding behavior, i.e., herding based on non-fundamental factors from spurious herding, i.e., herding based on fundamental factors. Their approach also allows herding behavior to emerge over time, as opposed to the restrictive identifying assumption of the Christie & Huang (1995) model that herding behavior is only manifested during extreme market movements.

In the spirit of CAPM, Hwang & Salmon (2004) start with the following equilibrium asset pricing equation:

\[ E_t(r_{it}) = \beta_{imt}E_t(r_{mt}) \]

where \( E_t \) is the conditional expectation at time \( t \), \( r_{it} \) and \( r_{mt} \) are the equilibrium returns on the \( i^{th} \) stock and market portfolio at time \( t \), respectively and \( \beta_{imt} \) is the systematic risk measure or the sensitivity of stock returns to the market return. In equilibrium, knowledge of the \( i^{th} \) stock \( \beta \) is sufficient to determine stock price. However, Hwang & Salmon (2004) argue that in the presence of herding behavior, investors’ beliefs compel them to follow market trends by matching individual stock returns with that of the market portfolio and disregard the equilibrium relationship implied by CAPM. Consequently,
biasing the stock betas based on the CAPM asset pricing equation and instead leading to the following relationship:

\[
\frac{E_t(r_{it})}{E_t(r_{mt})} = \beta_{imt}^b = \beta_{imt} - h_{mt}(\beta_{imt} - 1) \tag{A}
\]

Where \(E_t(r_{it})\) and \(\beta_{imt}^b\) reflect the biased expected return and biased beta of the \(i^{th}\) stock respectively and \(\beta_{imt}\) is the true beta of \(i^{th}\) stock. While \(h_{mt}\) is the latent parameter that represents aggregate herding behavior towards the market over time, conditional on market fundamentals. Though, the latent herding parameter changes over time but is bounded above and below by 1, i.e., \(|h_{mt}| \leq 1\) and \(h_{mt} > 0\) represents herding behavior towards the market. It is straightforward to verify that equation (A) reduces to the standard CAPM relationship if \(h_{mt} = 0\), i.e., in the absence of herding behavior we get: \(\beta_{imt}^b = \beta_{imt}\). While in the case of perfect herding towards the market \((h_{mt} = 1)\), we get \(\beta_{imt}^b = 1\), i.e., the return of each stock exactly equals the return on the market portfolio.

Hwang & Salmon (2004), also discuss the case of \(h_{mt} < 0\), which corresponds to the opposite of herding behavior or “adverse herding”, representing mean reversion towards the CAPM equilibrium. They propose that periods of herding are followed by periods of adverse herding and vice versa to correct mispricing.

However, given that both \(\beta_{imt}\) and \(h_{mt}\) are unobserved, Hwang & Salmon (2004) adopt a state-space modeling approach to extract these latent variables from the cross-sectional
standard deviation of $\beta_{imt}^b$. Since, the cross-sectional mean of $\beta_{imt} = 1$ by definition of the market portfolio, the standard deviation of $\beta_{imt}^b$ can be written as:

$$\text{Std}_c(\beta_{imt}^b) = \sqrt{E_c[(\beta_{imt} - h_{mt}(\beta_{imt} - 1) - 1)^2]}$$

Where $E_c$ denotes the cross-sectional expectation operator. We can factorize this expression to show that it is mathematically equivalent to:

$$\text{Std}_c(\beta_{imt}^b) = \sqrt{E_c[(\beta_{imt} - 1)^2(1 - h_{mt})^2]}$$

Now, given that $h_{mt}$ represents aggregate herding behavior common to all stocks, the cross-sectional expectation operator simply passes over $h_{mt}$ and allows us to rewrite the above expression as:

$$\text{Std}_c(\beta_{imt}^b) = \sqrt{E_c[(\beta_{imt} - 1)^2]}(1 - h_{mt})$$

From elementary statistics we know that this expression is identical to:

$$\text{Std}_c(\beta_{imt}^b) = \text{Std}_c(\beta_{imt})(1 - h_{mt})$$

Note that at any given time, $\frac{d[\text{Std}_c(\beta_{imt}^b)]}{dh_{mt}} < 0$, therefore the cross-sectional dispersion of betas would decrease (increase) with an increase (decrease) in the intensity of herding behavior towards the market portfolio. Intuitively, this makes sense because in the presence of herding behavior the beta of each individual stock would converge towards the beta of the market portfolio, i.e., 1, resulting in a smaller dispersion. For instance, in the extreme case of perfect herding, i.e., when $h_{mt} = 1$ we get $\text{Std}_c(\beta_{imt}^b) = 0$. Because perfect herding implies that investors completely ignore the CAPM relationship and
instead naively map the return of each stock to the market return, leading to a beta of unity for all stocks and a cross-sectional variance of zero. Finally, we can use logarithmic transformation to linearize the above expression and replace \( \log(1 - h_{mt}) \) by \( H_{mt} \) for notational convenience:

\[
\log[\text{Std}_e(\beta^b_{imt})] = \log[\text{Std}_e(\beta_{imt})] + H_{mt} \quad (B)
\]

The first term on the R.H.S represents the unobserved cross-sectional standard deviation of equilibrium (true) betas implied by CAPM and the second term is a function of the latent herding variable. We now turn our attention to the identifying assumptions of the Hwang & Salmon (2004) state-space model.

To arrive at the state-space analogue of the above model, Hwang & Salmon (2004) assume that equilibrium or true betas don’t change over time, just like in the conventional CAPM. This is a reasonable assumption from a theoretical standpoint, given that changes in stock beta are usually driven by either significant changes in the financial structure or significant changes in business activities. Both occurrences are usually rare and only likely to occur over a long horizon. Thus, Hwang & Salmon (2004) argue that empirical evidence of time varying betas (Harvey 1989 and Ferson & Harvey 1991) is driven by behavioral anomalies like herding rather than fundamental changes in true betas or the equilibrium relationship between \( E_t(r_{mt}) \) and \( E_t(r_{lt}) \). From an estimation standpoint, work of Ghysels (1998) supports their assumption of constant equilibrium or true betas. He explicitly shows that even under the assumption of time varying betas, no statistical
model is able to correctly capture time variation in betas and that pricing errors based on the traditional CAPM with a constant beta are smaller relative to pricing errors based on CAPMs with non-constant betas. Therefore, he recommends the use of constant equilibrium betas in CAPM asset pricing equations as opposed to time varying equilibrium betas.

Their identifying assumption implies that changes in \( \log[Std_c(\beta_{int})] \) over time can be attributed to changes in unobserved herding parameter. More specifically, in their model the dispersion of the true betas is time invariant although stochastic. Econometrically, this implies that \( \log[Std_c(\beta_{int})] = \mu_m + \nu_{mt} \), where \( \mu_m = E \log[Std_c(\beta_{int})] \) is the time invariant dispersion of true betas and \( \nu_{mt} \) is noise, given that \( \nu_{mt} \sim iid(0, \sigma^2_{mu}) \).

Accordingly, the state space representation of equation (B) is given by the following measurement and state transition equations, respectively:

\[
\text{Model V: } \begin{cases}
\log[Std_c(\beta_{int})] = \mu_m + H_{mt} + \nu_{mt} \\
H_{mt} = \phi_m H_{mt-1} + \eta_{mt}
\end{cases}
\]

The measurement equation is employed to linearly relate the observed time series, i.e., cross-sectional standard deviation of biased betas with the unobserved state, i.e., herding levels. Whereas, the state equation provides the evolution of the unobserved state through a Markovian process and the errors terms (\( \nu_{mt} \) and \( \eta_{mt} \)) are assumed to be independent of each other. Given this setup, the parameters of this state-space model can be estimated using Kalman filtering techniques. Kalman filtering techniques basically use recursive formulations of the first and second order conditional moments to estimate the unknown
parameters using a quasi-maximum likelihood algorithm, details can be found in Harvey (1989).

This state-space formulation allows herding behavior \((H_{mt})\) to evolve over time, where the parameter \(\phi\) measures the persistence of herding behavior. While, the existence of herding behavior rests upon the statistical significance of the empirical estimate of \(\sigma_{\eta}^2\), which is derived from the behavior of \(\eta_{mt} \sim iid(0, \sigma_{\eta}^2)\)\(^{139}\).

7.5 Estimation & Results

Before implementing the above-mentioned model, we need to construct a time series of the cross-sectional standard deviation of betas in the KSE. Evidently, this requires us to first estimate the firm level estimates of stock betas. Despite the simplicity of the task, there is a lot variation and almost no consensus in the literature on the best way to estimate firm level betas, especially with reference to the length of the estimation period. For example, Hwang & Salmon (2009), Messis and Zapranis (2014), and Caparrelli et al. (2004) employ rolling estimation techniques to estimate firm level betas using monthly data over 5-year periods. While, Hwang & Salmon (2004) and Rahman et al. (2015) use daily data over non-overlapping monthly intervals to estimate firm level betas. In lieu of our institutional environment, we employ the former approach because it is well known that stocks in emerging markets suffer from illiquidity, especially over daily intervals,

\(^{139}\)Note that when \(\sigma_{\eta}^2 = 0\), the measurement equation reduces to \(\log(Std_c(\beta_{mt})) = \mu_m + \nu_{mt}\), implying that herding behavior is not present. Also, the absolute value of estimates of \(\phi_m\) should be less than 1, in order to ensure that the process is stationary and does not explode.
and this can bias estimates of beta (Antoniou et al. 1997 and Andronikidi and Kallinterakis 2010). Moreover, as argued by Messis and Zapranis (2014), employing monthly returns instead of daily returns also reduces the estimation error in estimates of beta. Furthermore, they explain that herding is not a short-lived, ephemeral phenomenon but instead herding behavior is a persistent, slowly moving process that causes prices to deviate from fundamentals. Therefore, focusing on short-windows e.g. daily returns over monthly periods to compute the betas can be potentially misleading.

We use a simple one factor model to compute the betas, where the KSE-100 index is used as a proxy for the market portfolio. Given the tradeoff of between the estimation accuracy of firm level beta estimates and the number of observations available for the state-space model, we use rolling estimations over a three year period instead of a five year period. Following the approach of Caparrelli et al. (2004), we remove non-significant estimates of beta from the sample. In line with literature, the full sample mean of the estimated betas was close to 1 ($\bar{\beta}_m = 0.93$), suggesting that our sample forms a fairly well diversified portfolio. We compute the cross-sectional standard deviation of the estimated betas as:

$$Std_c(\hat{\beta}_{int}) = \sqrt{\frac{\sum_{i=1}^{N}(\hat{\beta}_{int}^b - \bar{\beta}_{int}^b)^2}{N}}$$

Since, our dataset comprises of monthly stock prices from Jan-2000 to Dec-2011, rolling estimations over a 3-year period leaves us with a total of 108 observations of cross-sectional standard deviation of biased beta. The summary statistics of cross-sectional standard deviation
standard deviation in levels along with its logarithm are summarized in Table 18. Based on the Skewness and Kurtosis test, the null hypothesis of normality was rejected in levels but accepted in logarithm at conventional levels of statistical significance.

Table 18 Summary Statistics: SD of OLS Betas

<table>
<thead>
<tr>
<th></th>
<th>Cross-Sectional SD of betas</th>
<th>Logarithmic Cross-Sectional SD of betas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0.400</td>
<td>-0.403</td>
</tr>
<tr>
<td>SD</td>
<td>0.061</td>
<td>0.069</td>
</tr>
<tr>
<td>Skewness</td>
<td>-0.269***</td>
<td>-0.603</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>2.472***</td>
<td>2.764*</td>
</tr>
</tbody>
</table>

We employed rolling estimations over 3-year window to estimate betas using a one factor market model with KSE-100 index used as the only factor. The estimated betas were used to obtain cross-sectional standard deviation of betas. Asterisks indicate statistical significance, ***, **, * represent significance at 1%, 5% and 10% respectively with a Null-hypothesis of normality.

Estimates from the state-space model using the stationary Kalman filter method are reported in table-19. The baseline model is reported in Column 1. For the sake of robustness, Column 2 reports the parameter estimates with an equally weighted portfolio of sample stocks used as the market portfolio instead of the KSE-100 index in the market model. Lastly, following Hwang & Salmon (2004), the augmented model in Column 3 conditions on other variables that may have potentially driven changes in the cross-sectional standard deviation of betas for example market return, realized volatility and monthly T-bill rates.
Table 19 Estimates of Herding Behavior from State Space Model

<table>
<thead>
<tr>
<th></th>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measurement Equation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu_m$</td>
<td>-0.3912***</td>
<td>-0.2967***</td>
<td>-0.3238***</td>
</tr>
<tr>
<td></td>
<td>(0.034)</td>
<td>(0.038)</td>
<td>(0.028)</td>
</tr>
<tr>
<td>$\sigma_{mu}$</td>
<td>0.0038</td>
<td>3.42e-8</td>
<td>0.0028</td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td>N/A</td>
<td>(0.018)</td>
</tr>
<tr>
<td>$c_1$</td>
<td></td>
<td></td>
<td>-0.6029</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.457)</td>
</tr>
<tr>
<td>$c_2$</td>
<td></td>
<td></td>
<td>-0.0032</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.003)</td>
</tr>
<tr>
<td>$c_3$</td>
<td></td>
<td></td>
<td>-0.8293**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.356)</td>
</tr>
<tr>
<td>State Equation:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varphi_m$</td>
<td>0.9467***</td>
<td>0.966***</td>
<td>0.9413***</td>
</tr>
<tr>
<td></td>
<td>(0.030)</td>
<td>(0.021)</td>
<td>(0.032)</td>
</tr>
<tr>
<td>$\sigma_{mn}$</td>
<td>0.0217***</td>
<td>0.0159***</td>
<td>0.0215***</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.002)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Signal: $\sigma_{mn}/SD(\log[Std_c(\beta^{b}_{int})])$</td>
<td>0.3120</td>
<td>0.2456</td>
<td>0.3117</td>
</tr>
<tr>
<td>log likelihood</td>
<td>254.0786</td>
<td>292.6418</td>
<td>256.2779</td>
</tr>
<tr>
<td>Schwarz’s information Criterion</td>
<td>-489.4658</td>
<td>-569.6783</td>
<td>-479.8462</td>
</tr>
</tbody>
</table>

Column 1 specification: measurement equation is given by $\log[Std_c(\beta^{b}_{int})] = \mu_m + H_{int} + \nu_{int}$ and the state equation is $H_{int} = \varphi_m H_{int-1} + \eta_{int}$. The model in Column 2 is identical to Column 1 specification, expect that the $\log[Std_c(\beta^{b}_{int})]$ is calculated using an equally weighted portfolio as opposed to the KSE-100 as the market index in the one factor model. Column 3: measurement equation is given by: $\log[Std_c(\beta^{b}_{int})] = \mu_m + H_{int} + c_1r_{mt} + c_2\log\sigma_{int} + c_3TB_t + \nu_{int}$ and the state equation: $H_{mt} = \varphi_m H_{mt-1} + \eta_{mt}$. Where the $r_{mt}$ represents the realized monthly return on KSE-100 index, $\sigma_{int}$ is the monthly realized volatility calculated using variations in daily data and $TB_t$ represents the government of Pakistan monthly treasury bill/policy rate. The respective errors terms are $\nu_{int} \sim iid(0, \sigma^2_{\nu_{mt}})$ and $\eta_{mt} \sim iid(0, \sigma^2_{\eta_{mt}})$. The signal-proportion value is calculated as the ratio of $\sigma_{int}$ and the sample standard deviation of $\log[Std_c(\beta^{b}_{int})]$). Standard errors are given below the parameter estimates and asterisks indicate statistical significance, where ***, ***, * represent significance at 1%, 5% and 10% respectively.
Discussion of Estimation Results

Even though variables in the measurement equation are potentially interesting, given our research objectives, the parameters $\sigma_m$ and $\phi_m$ in Table 19 are the primary focus of our analysis. The results of the baseline model in Column 1 show that $\sigma_m$ is statistically significant at the 1% level. Recall that a statistically significant estimate of $\sigma_m$, provides evidence in support of the herding behavior while the estimate of $\phi_m$ tells us about the dynamics of herding behavior. Estimates in Column 2 corroborate our findings and show that the presence of herding behavior is not sensitive to the choice of market index, albeit based on the information criterion the model in Column 1 (with KSE-100 index as the market index) provides a better fit, hence we use it as our preferred model.

The results of the augmented model in Column 3 clearly demonstrate that herding behavior extracted from the cross-sectional standard deviation of betas is robust to the inclusion of variables reflecting stock market fundamentals. Because if herding behavior vanished after controlling for market fundamentals in the measurement equation then we could conclude that changes in cross-sectional standard deviation of betas were driven by these fundamentals rather than herding. Though statistically significant, T-bill rate does not affect the herding dynamics, while market return is only marginally insignificant (p-value=0.132). Nonetheless inclusion of these variables improves the fit of the model (SBIC of -479.8462 compared to -489.4658 in the baseline model) and leads to a statistically significant reduction in $\mu_m$ (-0.3238 compared to -0.3912 in the baseline.
model), the time-invariant cross-sectional standard deviation of the true (equilibrium) betas.

Likewise, regardless of model specification, the estimates of $\Phi_m$ show that herding behavior is highly persistent in the KSE. The signal-proportion value ($\sigma_{m\eta}/SD(\log[Std_c(\hat{\beta}_l)])$) of approximately 0.30 implies that herding explains on average 30% of the variation in cross-sectional standard deviation of the observed (biased) betas. The relatively low signal-proportion value supports our hypothesis that herding behavior is highly persistent and smooth in KSE. Because compared to lower values, higher values of signal-proportion mean that dynamic evolution of herding behavior is not smooth (Hwang & Salmon 2004). To put our empirical estimates into context, we highlight findings on herding behavior in emerging markets from studies based on the beta-dispersion methodology. Using a dataset spanning 2002-2012, Rahman et al (2015) find presence of herding behavior in Saudi Arabia, a market dominated by domestic retail traders rather than institutional investors. However, a signal-proportion value of 0.70 suggests that herding behavior is not smooth in Saudi Arabia. Furthermore, Andronikidi and Kallinterakis (2010) show that the levels of latent herding increase after adjusting for thin-trading bias in Israel during the period 1997-2006. They also find that herding measures becomes smoother after controlling for thin-trading bias, for example in their case the signal-proportion value declines from 0.69 to 0.22 after controlling for thin trading bias.
Messis and Zapranis (2014) document several cycles of herding and adverse herding in Greece from 1995 to 2010. Interestingly, Solakoglu & Demir (2014) don’t find evidence of herding behavior in BIST30, an index representing the segment of the Borsa Istanbul (BIST) stock market dominated by investors with access to high quality information intermediation services. While, they find strong evidence in support of herding in the Second National Market (SMN), a segment dominated by local investors’ possessing smaller portfolios and facing high information costs. Hwang & Salmon (2004) document significant differences in herding behavior between US and South Korea during 1991-2002, herding behavior in South Korea is smoother (signal-proportion value of approximately 0.20) compared to US (signal-proportion value of 0.40). The overall empirical evidence suggests that cycles of herding behavior are more persistent and smoother in emerging markets compared to developed stock markets.

Though not always useful due to the differences in institutional settings and timeframes, nonetheless, the magnitude our parameter estimates are comparable to prior studies on emerging markets. For instance Solakoglu & Demir (2014) report $\sigma_{m\eta}$ of 0.035 in Turkey, Hwang & Salmon (2004) report $\sigma_{m\eta}$ of 0.086 in South Korea, Messis and Zapranis (2014) $\sigma_{m\eta}$ of 0.071 and Andronikidi and Kallinterakis (2010) report $\sigma_{m\eta}$ of 0.065 in Israel. Lower values of $\sigma_{m\eta}(0.022)$ in our case, reiterate that herding behavior is more persistent and smoother in the KSE compared to other emerging markets. Comparison of estimates of $\varnothing_m$ with the above-mentioned stock markets leads to the same conclusion.
Given that the estimates of $\sigma_{mn}$ are statistically significant at the 1% level across all specifications in Table 19, we can unambiguously conclude that herding behavior is present in the KSE, while, estimates of $\varphi_m$ show that herding behavior is persistent. In light of the relevant literature, we also observe that compared to other emerging markets, herding behavior in the KSE is relatively smooth. Next, in order to get a better understanding of the evolution of herding behavior in KSE, we exploit the state-space structure of the Hwang & Salmon (2004) model to back out the unobserved herding behavior in the KSE as $\hat{h}_{mt} = 1 - \exp(\bar{h}_{mt})$ from the baseline model. Figure 17 shows a line-plot of the predicted valued of $\hat{h}_{mt}$ over time.

The evolution of herding highlights many interesting patterns that are broadly consistent with the stylized facts associated with the growth of KSE. First note that prior to 2005, herding behavior was virtually non-existent, recall that as highlighted in Section 7.3 this period coincided with strong macroeconomic performance and positive firm performance indicators. In fact, in the jargon of Hwang & Salmon (2004), this period showed signs of “adverse” herding which is consistent with emphasis of investors on firm fundamentals to spot “good” stocks. However, post Jan-2005 we witness a strong, almost vertical rise in herding behavior, representing the so called “irrational exuberance” that usually follows sustained periods of positive growth. This effect lingers till mid-2006, after which we observe another surge that lasts till the beginning on 2008.
Figure 17 Evolution of Herding Behavior in KSE

As emphasized in Section 7.3, both macro and firm level indicators during 2005-2008 were not particularly impressive, therefore a plausible explanation for this surge in herding behavior is the “band wagon effect” that led to asset price bubble. As investors flocked to invest in the KSE, stock prices soared due to excess demand in the short-run, resulting in higher returns, the higher returns attracted even more investors who overlooked fundamentals and the cycle continued. This “story” is supported by some stylized facts. For example Appendix-K shows that market capitalization monotonically increased from approximately 30% of the GDP at the end of 2004 to approximately 50% of the GDP by end of 2007. The trend of KSE-100 index in figure 1 also shows that KSE experienced rapid growth during this period. This period of exponential growth also coincided with relatively high volatility as market capitalization reached a record Rs. 70 billion in 2007. These developments our consistent with the theoretical literature on
increasing levels of herding, i.e., high returns and “churn” created by noise trader demand (De Jong et al. 1990).

Remarkably, one can clearly observe a sharp decline in herding levels beginning 2008. We present two explanations to explain this trend. Perhaps the decline was due to the imminent shock of the global financial crisis and the rising uncertainty in the future outlook of the domestic economic environment due to the political crisis. Hwang & Salmon (2004) argue that herding levels decrease during periods of shocks because the market becomes difficult to “predict” and investors turn towards fundamentals resulting in what they refer to as adverse herding. On the other hand, during periods of relative certainty (positive or negative), investors are prone to follow the market sentiment and become too optimistic or pessimistic resulting in herding. Another, explanation of the observed decline in herding behavior is derived from the folk-theorem that asset price bubbles often burst at their peak, i.e., after the extent of mispricing caused by herding exceeds a certain threshold, asset prices return towards equilibrium or mean reversion in asset prices. These explanations are not mutually exclusive, and in all likelihood both mechanisms contributed to the decline of herding levels at the start of 2008.

140General Musharraf came to power as a result of military coup in 1999 and oversaw a period of political stability and economic growth. A tussle with the Judiciary ensued after the sacking of the Chief Justice in March 2007 and eventually led to his ouster from power. Emergency rule was imposed in September 2007 followed by mass arrests of political workers of the opposition party. 2008 was a year of great political uncertainty, on her return the former exiled Prime Minister Benazir Bhutto was assassinated while addressing a political rally in Islamabad on 27th December 2007. This sparked country wide protests and general elections were postponed due to the prevailing law and order situation. After a spate of violence and bomb blasts, Benazir Bhutto party won the general election in 2008 and impeached General Musharraf from the presidential office in 2009.
Though not obvious, but the evolution of herding behavior is broadly consistent with the changes in the explanatory power of accounting information. The primary difficulty in directly observing the effect of herding levels on the value relevance of accounting information draws from the fact that our measure of the former is based on a monthly frequency while the latter is based on an annual frequency. In order to circumvent this problem, we take simple average of monthly herding levels over the financial year, this allows us to clearly observe the effect of herding levels on the explanatory power of accounting information, without compromising the economic intuition that excessive herding behavior leads to divergence of stock prices from firm fundamentals and hence a reduction in the explanatory power of accounting information\textsuperscript{141}. Figure 18 shows the inverse relationship between degree of herding and the explanatory power of accounting information.

The line plot shows that during 2002-2005, the explanatory power of accounting information was significantly above the sample mean, although on a declining trend. While at the same time herding levels, though insignificant but were gradually on the rise. From 2005-2007 we see a sharp increase in herding behavior and a corresponding decline in the explanatory power of accounting information, clearly suggesting that stock prices driven by herding behavior diverged from firm fundamentals during this asset price bubble period. The bubble burst in 2008 and the period 2008-2009, saw a sharp

\textsuperscript{141}Interpolation of value relevance measure over months is both unintuitive and statistically invalid. If we interpolate R-square from annual regressions over monthly frequency than our dependent variable will have minimal variation. For example for a given financial year, there will be 12 consecutive data points where the dependent variable does not change while the independent variable varies. The same situation will arise in the next year and so on. Obviously regression estimates will be biased towards insignificance.
decline in herding levels due to reasons explained above. While, the value relevance of financial statements improved from 2008 to 2009, suggesting that prices started to converge to fundamentals.

Figure 18 The Inverse Relationship between Herding Behavior & the Explanatory Power of Accounting Information

Author: Since we used 3 year rolling window to estimate betas, latent herding levels are only available from Jan-2002. The red line represents $\bar{\vec{h}}_{int}$, i.e., average of monthly herding levels over a given financial year e.g. $\bar{\vec{h}}_{int}$ corresponding to 2003 represents monthly average of herding levels from Jul-2002 to Jun-2003. The green line represents explanatory power of accounting information, i.e., the Adj-R-square of value relevance regressions from the base line model.

Though our analysis presents a strong narrative and provides suggestive evidence in favor of our original hypothesis that increases in levels of herding led to the decline of the value relevance of financial statements but it lacks the rigor to establish a robust association. At the same time, the small sample size (9 observations) severely limits the power of statistical tests; nevertheless we fit a simple regression model with adjusted R-square from the value relevance regressions as the dependent variable and average herding levels from the state-space model as the independent variable in column 1 of
Table 20. As expected the coefficient on herding levels is negative suggesting that increases in herding levels lead to divergence of stock prices from firm fundamentals and hence a reduction in the explanatory power of accounting information vis-à-vis stock prices. But the large standard errors, most probably due to small sample size or perhaps model misspecification mean that null hypothesis cannot be rejected at conventional levels (p-value 0.23).

In light of our framework of stock price dynamics, we augment the baseline model in Column 1 with our measure of average earnings quality, i.e., earnings persistence ($\rho_1$) in order to control for changes in earnings properties over time. The estimates of this model are reported in Column 2. The overall fit of the model clearly improves, as R-square more than doubles. While, the positive sign on earnings persistence is in line with our expectations that increases in earnings quality improve the value relevance of financial statements and vice versa (Lipe 1990). Furthermore, the coefficients on both herding levels (p-value 0.09) and earnings persistence (p-value 0.03) are now statistically significant at conventional levels, signifying that perhaps the model in Column 1 was severely misspecified. In order to reaffirm this intuition, Column 3 reports the regression results of the value relevance of financial statements on earnings quality only. The R-square falls to approximately zero and nothing is statistically significant, lending support to the model misspecification explanation. Such a behavior is usually observed in the presence of severe misspecification errors especially omitted variable bias and once we
control for it by including proxies for earnings quality ($\rho_t$) and stock price quality($\bar{h}_{mt}$), we get a better fit and statistical significant estimates.

| Table 20 Decline in the Value Relevance of Accounting Information-Determinants |
|-----------------------------------------------|-------------------------------|-------------------------------|
| Column 1               | Column 2                | Column 3                   |
| $\alpha$               | 0.112**                  | -0.196*                    | 0.062                      |
|                        | (0.03)                    | (0.09)                      | (0.11)                     |
| $\beta_1$              | -0.316                    | -0.382*                    |
|                        | (0.24)                    | (0.19)                     |
| $\beta_2$              |                          | 0.311**                   | 0.073                      |
|                        |                          | (0.10)                     | (0.02)                     |
| R-square               | 15.35                     | 34.76                       | 1.73                       |

The models are as follows: Column 1 specification: $R^2_t = \alpha + \beta_1 \bar{h}_{mt} + \epsilon_t$, Column 2 specification: $R^2_t = \alpha + \beta_1 \bar{h}_{mt} + \beta_2 \rho_t + \epsilon_t$, and Column 3 specification: $R^2_t = \alpha + \beta_1 \rho_t + \epsilon_t$. Where $R^2_t$ represents the adjusted R-square from the year by year value relevance regressions reported in Table 6, $\bar{h}_{mt}$ is the latent state variable from Table 10 reflecting average herding levels, $\rho_t$ is earnings persistence estimates from Table 7 reflecting earnings quality. We took simple average of monthly herding levels over the financial year to compute $\bar{h}_{mt}$ from $h_{mt}$, the financial year in KSE runs from 1st July to 30th June. Standard errors are given below the parameter estimates and asterisks indicate statistical significance, where ***, **, * represent significance at 1%, 5% and 10% respectively.

Overview

Before concluding this Section, we review the major results. First, after taking into consideration the sudden economic spurt in Pakistan during early 2000 and the opaque information environment we make a compelling case for the existence of herding behavior in the KSE. Empirical estimates from the Hwang & Salmon (2004) state-space model provide strong evidence in support of this hypothesis. We also show that that the existence of herding behavior is robust to the inclusion to key macroeconomic
fundamentals like direction of stock market, volatility and Treasury bill rates. Second, the dynamic pattern of unobserved levels of herding behavior, backed out from the state-space model, is, to a large extent, consistent with the stylized facts associated with the growth of the KSE can explain. In particular, we find insignificant levels of herding between 2002-2005, this is followed by a sharp increase in 2005, which continues till 2008 and is followed by a steep decline. Third, figure 18 highlights the inverse relationship between the value-relevance of financial statements and herding behavior, especially during periods of excessive herding. This inverse relationship is confirmed by empirical estimates presented in Table 20. Estimation results in Table 20 also lend support to our stock price dynamics framework (Section 2) by showing that both stock price quality and earnings quality were important determinants of the reduction in explanatory power of accounting over time in KSE. And ignoring either can result in severe model misspecification problems. Although, the small sample size, limits the statistical power of these conclusions.

8 Macroeconomic Determinants of Herding Behavior

Keeping in the view the opaque institutional environment and the peculiar economic circumstances associated with the exponential growth of the KSE, the preceding analysis has documented the existence of herding behavior in the KSE and highlighted its adverse effects on the informativeness of stock prices. But an important question remains, apart from an enabling institutional environment and positive economic shocks, which factors
triggered or provided impetus to herding behavior? Answer to this question, has important policy ramifications.

Economists generally concur that monetary expansion has a positive effect on assets markets in general and stock markets in particular (Muradogalu and Metin 1996). And monetary expansion is expected to lead to an increase in investments in the stock market. However, all other things equal, higher investments in stock translate into higher stock prices in the short run which induces further investment in stocks; the feedback process may continue unabated, eventually transpiring into asset price bubbles (Cecchetti 2000). In similar vein, Brunnermeier (2008) and Acharya & Naqvi (2012) have shown that positive liquidity shocks to the banking system can lead to asset price bubbles. The 2008 financial crisis has reinforced both views. Likewise, Reinhard & Rogoff (2009), provide numerous case studies to highlight that bubbles in emerging markets are often preceded by cheap credit. The intuition behind the burgeoning theoretical literature on monetary aggregates and asset price bubbles is straightforward, i.e., by lowering the opportunity cost of investments; excess liquidity encourages risk taking behavior. Therefore, we argue that buoyed by monetary expansion investors overlooked fundamentals and instead choose to herd on the positive market sentiment.

Another interesting mechanism, perhaps peculiar to less developed countries, is related to the effect of foreign portfolio investment on herding behavior. Investors in less developed countries like Pakistan see foreign portfolio investments as a “hard” indicator of the stock
market performance, under the assumption that capital flows from developed countries are a result of high-quality due diligence. Moreover, given the opaque information environment, i.e., underdeveloped information intermediation industry and inadequate investment advisory services, the direction of foreign portfolios provides valuable information on the “true” value of stocks and functions as an important driver of herding behavior. Anecdotal evidence supports this view. For example in March-2015, the KSE suffered a strong bout of volatility following news that foreign institutional investors pulled out approximately $130 million from the stock market (Dawn 2015). Though the outflow was negligible compared to the overall market capitalization, nonetheless it created panic among the investors and led to a large decline in the market, a clear manifestation of herding behavior. Several episodes of similar nature in the past show the vulnerability of the stock market to sentiments created by foreign portfolio investment. We interpret this mechanism, as the information effect, whereby foreign portfolio flows are viewed by the market participants as a reliable signal of market outlook and thus serve as a “factor” that investors herd on.

Under the assumption, that herding behavior is captured by the latent herding parameter in the Hwang & Salmon (2004) state space model, we can empirically test the validity of the abovementioned mechanisms identified in the theoretical literature on asset price bubbles. To this end, we collect data on monetary aggregates (M1), average deposit rates and net foreign portfolio flows in Pakistan at a monthly frequency from the Global Financial Database (GFD) & State Bank of Pakistan respectively. However, given the
time series nature of the data, we need to carefully investigate the properties of the data before specifying a regression model. Because OLS estimates based on non-stationary data are generally spurious. Likewise, failure to account for cointegration between non-stationary I(1) variables can lead to model misspecification.

Table 21 Stationarity-Unit Root Tests

| Variables                      | Augmented Dicky-Fuller | Phillips-Perron Unit Root |
|                               | Unit Root Test          | Test                      |
|                               | Levels | First Differences | Levels | First Differences |
| Herding ($h_{mt}$)            | -1.834 | -3.648***         | -1.899 | -11.01***         |
| M1-Monetary Aggregates        |        |                   |        |                   |
| ($m_t$)                       | -2.256 | -6.294***         | 0.424  | -9.93***          |
| Deposit Rate ($d_t$)          | -1.443 | -3.93***          | -0.373 | -9.75***          |
| Net Foreign Portfolio         |        |                   |        |                   |
| Investment ($n_t$)            | -2.934*| -9.773***         | -10.30***| -26.38***         |
| KSE-100 Return ($R_{mt}$)     | -6.60***| N/A               | -8.39***| N/A               |

All variables are recorded at the monthly frequency. Herding ($h_{mt}$) a proxy of herding behavior was backed out from the estimation results of the Salmon & Hwang state space model in Table 4. KSE-100 Return ($R_{mt}$) represents realized monthly return using within month daily price data retrieved from KSE website. M1-monetary aggregates ($m_t$) measured in trillion Rs, represent money in circulation (according to definition of money in M1) retrieved from Global Financial Database (GFD). While Data on net foreign portfolio investment (in billions) and average deposit rates was taken from State bank of Pakistan database. The dataset spans Jan-03 to Dec-11, for a total of 108 observations. Based on the Johansen (1995) test we did not find cointegration between any one of the I(1) variables above.
Table 21 reports the results from the augmented Dicky-Fuller unit root test and the Phillips-Perron unit root. Results from both tests clearly show that the null of non-stationarity cannot be rejected if herding, M1 and deposit rate are measured in levels, but it is easily rejected upon taking first differences. Note that by definition the net foreign portfolio investment variable is a first differenced variable and thus stationary, therefore we do not take another first difference. The same argument applies for the KSE return. Based on the results of Johansen (1995) cointegration test (results not reported) we concluded that the none of the I(1) variables above are cointegrated.

Given these finding we estimate the following regression model, denoting an essentially short term, contemporaneous relationship between herding levels and macroeconomic factors:

$$\Delta h_{mt} = \beta_1 \Delta m_t + \beta_2 n_t + \beta_3 \Delta d_t + \sum_{k=1}^{n} \beta_{k+3} x_t^{k-1} + \epsilon_t$$

Although we lose information by first differencing, nonetheless the intuition remains the same, i.e., we seek to understand how changes in herding behavior are driven by changes in certain macroeconomic factors. A positive and statistically significant effect of M1 and net foreign portfolio investment on herding levels will lend support to the abovementioned hypotheses, i.e., positive effect of liquidity and information flows on herding behavior. For the sake of robustness, we augment the baseline model with other controls including lagged herding behavior and monthly realized return of KSE. Table 22 shows OLS estimates of Model IV.
<table>
<thead>
<tr>
<th></th>
<th>Column 1</th>
<th>Column 2</th>
<th>Column 3</th>
<th>Column 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Money Supply</td>
<td>0.048**</td>
<td>0.044**</td>
<td>0.044*</td>
<td>0.048**</td>
</tr>
<tr>
<td></td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
<td>(0.02)</td>
</tr>
<tr>
<td>Portfolio Investment</td>
<td>0.056*</td>
<td>0.059*</td>
<td>0.058*</td>
<td>0.059*</td>
</tr>
<tr>
<td></td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.03)</td>
<td>(0.03)</td>
</tr>
<tr>
<td>Deposit Rate</td>
<td>-2.74</td>
<td>-2.70</td>
<td>-3.21</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.34)</td>
<td>(2.38)</td>
<td>(2.19)</td>
<td></td>
</tr>
<tr>
<td>KSE-100 Return</td>
<td></td>
<td></td>
<td></td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.01)</td>
</tr>
<tr>
<td>Lagged Herding</td>
<td></td>
<td></td>
<td></td>
<td>-0.04</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.10)</td>
</tr>
<tr>
<td>R-Square</td>
<td>2.66%</td>
<td>4.47%</td>
<td>4.27%</td>
<td>5.60%</td>
</tr>
<tr>
<td>Portmanteau white noise test</td>
<td>31.3</td>
<td>29.2</td>
<td>29.16</td>
<td>27.39</td>
</tr>
</tbody>
</table>

*Herding (h<sub>new</sub>) a proxy of herding behavior was backed out from the estimation results of the Salmon & Hwang state space model in Table 4. KSE-100 Return (R<sub>new</sub>) represents realized monthly return using within month daily price data retrieved from KSE website. M<sub>1</sub>-monetary aggregates (m<sub>1</sub>) measured in trillion Rs, represent money in circulation (according to definition of money in M1) retrieved from Global Financial Database (GFD). While Data on net foreign portfolio investment (in billions) and average deposit rates was taken from State bank of Pakistan database. The dataset spans Jan-03 to Dec-11, for a total of 108 observations. Newey-West standard errors are given below the parameter estimates and asterisks indicate statistical significance, where ***, **, * represent significance at 1%, 5% and 10% respectively.

The regression results provide strong evidence in support of the nexus between excess liquidity and changes in herding behavior. Whereby, changes to the monetary base effect herding behavior. For example, β<sub>1</sub> the coefficient on M1 is statistically significant in all of specifications. Similarly, the positive effect of net foreign portfolio flows on herding behavior is also documented regardless of model specification. In Column II we augment the baseline model with average deposit rate, the coefficient on deposit rate is negative as
expected (a higher deposit rate corresponds to a tight monetary policy) but statistically insignificant at conventional levels of significance. One possible explanation for statistical insignificance draws from the nature of the deposit rate data, which is a weighted average of interest rate paid on all types of deposit accounts, including long term deposits. Whereas, short term deposit rates are more likely to influence changes in herding behavior given the short term investment horizon of investors in the KSE.

In column 3 we add the lag of KSE-100 index return to control for the effect of market movements on herding behavior. We cannot, include contemporaneous market return in the model due to the endogeneity problem, i.e., high herding levels lead to high returns today whilst high returns in turn promote herding behavior. The results are qualitatively similar to Column I and Column II, although the overall fit of the model deteriorates slightly. We also estimated the model with other key macroeconomic variables vis-à-vis the Pakistan economy e.g. remittances, exchange rates and T-bill rates, but none had any meaningful impact on herding behavior. Given the persistence of herding behavior, we include the lagged values of changes in herding levels in the model. The resulting specification in Column IV is our preferred model based on model fit and diagnostics tests. The Portmanteau white noise test shows that the null hypothesis of serially uncorrelated errors cannot be rejected in all specifications, suggesting that our empirical models are sufficiently well specified.
Overall the empirical results in Table 22 lend support to the hypothesized relationships in the theoretical literature on asset price bubbles. First, the coefficient on M1 is positive and statistically significant (p-value 0.02%) implying that an expansionary monetary policy adds impetus to herding behavior and vice versa. Likewise the coefficient on deposit rates is negative although marginally insignificant (p-value 0.14) in our preferred specification (columns-IV). Therefore, we can conclude that expansionary monetary policy encourages herding behavior. Second, consistent with anecdotal evidence in the KSE, foreign portfolio investment (p-value 0.08) reinforces herding behavior. Therefore, foreign portfolio investment can be viewed as an informational factor indicative of future stock market performance. In the presence of an opaque domestic information environment domestic investors simply herd on foreign portfolio investment flows.

These finding have important policy ramifications. Firstly, stock market bubbles can be an unintended adverse effect of expansionary monetary policies originally designed to promote economic growth. In fact, this was a major lesson of the 2008 financial crisis. Consequently, many economists have urged central banks to actively counteract stock market bubbles by “leaning against the wind”, i.e., pursuing contractionary monetary policies to counteract asset price bubbles even at the cost of temporarily deviating from the inflation/output targets (Gali 2013). From a developing country context, Rafiq (2015) calibrates a structural model developed to study the interaction of monetary policy and stock market bubbles with data from Bangladesh to show that monetary policy may have unintended spillovers with respect to stock market bubbles. Therefore, policy makers
need to look beyond the conventional output and inflation objectives of monetary policy in order to carefully consider the effects of monetary policy on stock market bubbles.

Second, foreign portfolio investment flows or “hot” money can have a large effect on investor sentiment in stock markets characterized by institutional voids and weak price discovery processes. Under these conditions, unregulated flows of foreign portfolio funds may increase volatility, undermining the long term growth of underdeveloped stock markets. Therefore, policy makers need to carefully weigh the cost and benefits of maintaining a certain degree of stock market oversight vis-à-vis foreign portfolio investment versus a complete transition to stock market liberalization.

Of course, herding behavior and stock market bubbles are a complex phenomenon, arising from the interaction of several confounding factors. Therefore, many identification issues can be raised. Nonetheless, at the very least, the abovementioned analysis captures a strong association between herding behavior, monetary policy and foreign portfolio investments.

9 Conclusions

In this Chapter, we examined the nature of the relationship between firm-specific accounting information and stock prices in the KSE, an emerging stock market that has witnessed phenomenal growth over the past decade. Financial and accounting data for 100 representative firms listed on the KSE from 1999 to 2011 was meticulously collected
from various publicly available sources of information. The utilization of a new dataset, rigorous empirical methodology and an interesting institutional context make this paper an important contribution to the growing literature on emerging stock markets. The major findings of the paper can be divided into parts.

First, within the value relevance regression framework, we use the information capitalization approach (Morck et al. 2000) to motivate an empirical test of the hypothesis that KSE is a market devoid of economic reality (Khawaja and Mian, 2003; Azad et al., 2014). Thereafter, we highlight the common theoretical underpinnings and evaluate the econometric properties of the Ohlson (1995) price model and the Easton and Harris (1991) return model. Estimation results based on both models clearly show that accounting information is an important determinant of stock prices in the KSE. In addition, consistent with prior accounting literature, we find that the explanatory power of accounting information shifts from earnings (income statement) to book values (balance sheet) in case of negative earnings and firm size is inversely related to stock returns. While, we acknowledge that capitalization of accounting information into stock prices and trade based market manipulation are not mutually exclusive outcomes but at the same time attributing the entire growth of a stock market over a period of 13 years to colluding brokers is difficult to justify in theory. At the very least, our findings suggest that the effect of trade-based manipulation on the growth of KSE was greatly exaggerated and warrant a reconsideration of the hypothesis put forward by (Khawaja & Mian 2003) that KSE is a ‘phantom’ stock market.
On the other hand, though trade trade-based market manipulation in the KSE has attracted interest (Azad. et al., 2014), but in reality, it is notoriously difficult to detect and often confused with volatility (Allan & Gale 1992). Nobel laureate Fama (1991) referred to this issue as the ‘joint hypothesis problem’, whereby bubbles in stock markets are indistinguishable from rational time-varying expected returns. Fama (1991, p. 1581) explained that ‘a ubiquitous problem in time series tests of market efficiency, with no clear solution, is that irrational bubbles in stock prices are indistinguishable from rational time-varying expected returns’. Therefore, high volatility and manipulation are not always synonymous.

The second half of this Chapter primarily deals with the question why did the explanatory power of accounting information decline over time? Again, by using the information capitalization approach, we draw attention to different mechanisms that might have led to the observed decline in the value relevance of accounting information, e.g., increased accessibility of non-accounting sources of information, adverse changes in earnings quality and stock price quality. We critically analyze each explanation and find that earnings quality proxied by earnings persistence and earnings predictability experienced a marginal decline over time. We also find support for the earnings lack of timeliness hypothesis but controlling for it does not change the overall decline in the value relevance of accounting information. While, the stylized facts associated with the information intermediation industry in KSE allows us to rule out increased accessibility of non-accounting sources of information as a valid explanation.
Thereafter, we employ the theoretical literature on herding behavior alongside the macroeconomic developments in early 2000 and the opaque institutional environment in KSE to argue that “noise trading” driven by herding behavior led to a divergence of stock prices from firm fundamentals in the KSE. Under the assumption that accounting information is associated with firm fundamentals, this phenomenon resulted in the observed decline in the explanatory power of accounting information. After highlighting the identifying assumptions of the return dispersion methodology (Christie & Huang 1995; Chang et al. 2000) and beta dispersion methodology (Hwang & Salmon 2004), we conclude that the latter is a more appropriate measure of herding behavior, given the nature of our research questions. Our empirical estimates from the Hwang & Salmon (2004) state space model establish the existence of herding behavior in the KSE and also illustrate that the evolution of herding behavior is broadly consistent with macroeconomic developments in Pakistan. Lastly, though limited by small sample size, estimates from a simple regression of value relevance of financial statements on earnings quality and herding levels corroborates our narrative. In particular increasing levels of herding negatively impacted the explanatory power of accounting information, especially during periods of excessive herding, while, a decline in earnings persistence also had a negative effect on value relevance of financial statements. Lastly, in light of the theoretical literature on asset price bubbles, we find that increases in liquidity (expansionary monetary policy) and foreign portfolio investment were key drivers of herding behavior.
These findings are not without important caveats. The level of noise trading and its impact on stock prices is difficult to observe directly, let alone measure accurately. Consequently, as researchers we have instead indirectly gauged levels of noise trading by estimating the extent to which actual stock prices deviate from their associated intrinsic values. Unfortunately, as researchers we cannot observe intrinsic values either and have to rely on some type of equilibrium pricing model to pin down intrinsic values. Therefore, under this approach any empirical test of changes in levels of noise trading is also a joint test of the equilibrium pricing model (CAPM in our case). Put simply, deviations of actual stock prices from the associated intrinsic values could be either due to increasing levels of noise or a misspecified equilibrium pricing model. Unfortunately, the financial economics literature is yet to find an acceptable solution to this “joint hypothesis” problem. At the same time, we also believe that like all economics models CAPM is a paradigm, a theoretical construct to formally think about interesting problems. Given that no market is perfectly “perfect” or perfectly “imperfect”, we see no reason why the CAPM cannot be utilized to study herding behavior in KSE.

The paper has important policy implications. First, the paper is a significant step towards explaining the exponential yet enigmatic growth of capital markets in Pakistan from 1999 to 2011. Second, although, our sample is somewhat dated, nevertheless, the simultaneous growth of the KSE in the post 2008 era and the increasingly low explanatory power of accounting information between 2008-2010 does not bode well for investors. Third, the evolution of herding behavior highlights that short sighted policies during periods of
rapid economic growth, for example cheap credit and abolishment of capital gains tax in Pakistan, can inadvertently induce herding behavior, lead to asset price bubbles, and result in misallocation of valuable resources. At the same time, institutional voids e.g. high information costs and limited participation of institutional investors increase the chances of bubbles in the future and instability. Finally, strong evidence of herding behavior in KSE highlights that behavioral biases of investors are another important risk factor in emerging markets.

It would be interesting to see if the hypothesized inverse relationship between value relevance of accounting information and herding levels holds true in the KSE post 2011 and in different countries with different institutional settings. Also, given our measure of earnings quality is limited to earnings persistence; research that employs additional accounting based measures of earnings quality like the Jones (1991) accrual model will be useful. The integration of accounting and finance models is another promising direction, however, one commonly encountered problem in this type of interdisciplinary research is frequency mismatch, for example high frequency data in finance but annual or at best quarterly data in accounting. Obviously, this leads one to average over the lower frequency, leading to a significant reduction in statistical power. On the other hand, by allowing researchers to back out unobserved herding behavior, Kalman filtering techniques have opened up interesting avenues for future research. For example, time series analysis to study the drivers of herding behavior, i.e., identifying macroeconomic factors that influence herding levels or exploring the application of herding levels as a
factor in traditional asset pricing models. It also allows us to empirically test predictions of theoretical models of herding behavior, for example are periods of high stock market volatility caused by herding levels after controlling for other variables?
References


Oxford Policy Management 2006 Poverty and Social Impact Assessment: Pakistan Microfinance Policy


Appendix A: Proof of Proposition 2A in Chapter 1

Since the RHS of both Equation 1 and Equation 2 equals zero, we equate them and after some simplifications we get:

\[ f((c + 1)\bar{a}) - f((c + 1)\alpha) + \left[ \frac{\bar{a}f'((c + 1)\bar{a})}{N} - \alpha f'((c + 1)\alpha) \right] (c + 1) = 0 \]

Now in order to show that defaults are inefficiently high due to intra-firm competition we need to prove that \( f((c + 1)\bar{a}) > f((c + 1)\alpha) \), which essentially boils down to establishing \( \bar{a} > \alpha \) since \( f(.) \) is an increasing function by Proposition 1B. A direct approach is not feasible so we employ the method of proof by contradiction. Let \( \alpha \geq \bar{a} \) then note that:

(a) By Proposition 1B \( f'(.) > 0 \), so if \( \alpha \geq \bar{a} \) then \( f((c + 1)\alpha) \geq f((c + 1)\bar{a}) \)

(b) By earlier assumption of \( f''(.) > 0 \), if \( \alpha \geq \bar{a} \) then \( f'((c + 1)\alpha) \geq f'((c + 1)\bar{a}) \)

(c) Now if \( \alpha \geq \bar{a} \), it must be that \( \alpha > \frac{\bar{a}}{N} \), as long as \( N > 1 \) where \( N > 1 \) represents competition.

Combining (a)-(c), we know that the LHS is always negative yet the RHS equals zero. Therefore, \( \alpha \geq \bar{a} \) is not feasible solution and it must be that \( \bar{a} > \alpha \). Hence, \( f((c + 1)\bar{a}) > f((c + 1)\alpha) \), i.e., sub optimally high default rates in the presence of intra-firm competition.
Appendix B: Derivation of Equation 3 in Chapter 1

The following simplifications involve dense yet simple algebra. We try to be as coherent as possible without missing out important details or stating the obvious. The FOC for \( \{\alpha_i\} \) after substituting the envelope theorem condition and the law of motion for lending reserves was shown to be:

\[
 r^* \left( 1 - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \right) - r^* (c + 1) \alpha_i f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \]

\[
 - \frac{c}{f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \alpha_i + \alpha_i + c \alpha_i}
\]

\[
 - \frac{\delta c \alpha_i \left( f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + \alpha_i (c + 1) f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + \bar{r}c + \bar{r} \right)}{(f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \alpha_i + \alpha_i + c \alpha_i)^2}
\]

\[
= 0
\]

Simplifying the last two terms we get:

\[
 r^* \left( 1 - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \right) - r^* (c + 1) \alpha_i f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \]

\[
 - c \left[ f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + 1 + c + \delta f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + \delta \alpha_i (c + 1) f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + \delta (\bar{r}c + \bar{r}) \right]
\]

\[
\alpha_i \left( f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + 1 + c \right)^2
\]

\[
= 0
\]
Now further simplifying and multiplying throughout by \( \alpha_i(f(\sum_{j=1}^{N} \alpha_j(c + 1)) + 1 + c)^2 \) we get:

\[
\begin{align*}
  r^* \alpha_i \left( 1 - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \right) \left( f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + 1 + c \right)^2 \\
  - r^* (c + 1) \alpha_i^2 f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \left( f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + 1 + c \right)^2 \\
  - c(1 + \delta) f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) - c\delta \alpha_i (c + 1) f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \\
  - c\delta(\bar{r}c + \bar{r}) - c(1 + c) = 0
\end{align*}
\]

Now we sum over the F.O.Cs for all \( N \) mfs:

\[
\begin{align*}
  r^* \left( \sum_{j=1}^{N} \alpha_j \right) \left( 1 - f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \right) \left( f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + 1 + c \right)^2 \\
  - r^* (c + 1) \left( \sum_{j=1}^{N} \alpha_j^2 \right) f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \left( f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) + 1 + c \right)^2 \\
  - c(c + 1) \delta \left( \sum_{j=1}^{N} \alpha_j \right) f' \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) \\
  - Nc(1 + \delta) f \left( \sum_{j=1}^{N} \alpha_j (c + 1) \right) - N(c\delta(\bar{r}c + \bar{r}) + c + c^2) = 0
\end{align*}
\]
Now let $\alpha = \ldots \alpha_{i-1} = \alpha_i = \alpha_{i+1} = \ldots \alpha_N = \alpha^*$ denote the symmetric Nash Equilibrium:

$$r^*N \alpha^*(1 - f(N \alpha^*(c + 1)))(f(N \alpha^*(c + 1) + 1 + c)^2$$

$$- r^*(c + 1)(N \alpha^*)f'(N \alpha^*(c + 1))(f(N \alpha^*(c + 1) + 1 + c)^2$$

$$- c(c + 1)\delta(N \alpha^*)f'(N \alpha^*(c + 1) - Nc(1 + \delta)f(N \alpha^*(c + 1))$$

$$- N(c\delta(\bar{r}c + \bar{r}) + c + c^2) = 0$$

Finally let $\sum_{j=1}^N \alpha^* = \bar{\alpha}$ be the aggregate lending in this market structure, substituting we get:

$$r^*\bar{\alpha}(1 - f(N \alpha^*(c + 1)))(f(\bar{\alpha}(c + 1) + 1 + c)^2$$

$$- \frac{r^*(c + 1)(\bar{\alpha})^2f'(\bar{\alpha}(c + 1))(f(\bar{\alpha}(c + 1) + 1 + c)^2}{N}$$

$$- c(c + 1)\delta(\bar{\alpha})f'(\bar{\alpha}(c + 1) - Nc(1 + \delta)f(\bar{\alpha}(c + 1))$$

$$- N(c\delta(\bar{r}c + \bar{r}) + c + c^2) = 0$$

Dividing throughout by $N$ gives us equation-3, which implicitly defines the aggregate default rates in this market structure:

$$\frac{r^*\bar{\alpha}(1 - f(\bar{\alpha}(c + 1)))(f(\bar{\alpha}(c + 1) + 1 + c)^2}{N}$$

$$- \frac{r^*(c + 1)(\bar{\alpha})^2f'(\bar{\alpha}(c + 1))(f(\bar{\alpha}(c + 1) + 1 + c)^2}{N^2}$$

$$- \frac{c(c + 1)\delta(\bar{\alpha})f'(\bar{\alpha}(c + 1))}{N} - c(1 + \delta)f(\bar{\alpha}(c + 1))$$

$$- (c\delta(\bar{r}c + \bar{r}) + c + c^2) = 0$$

351
Appendix C: Derivation of Equation 4 in Chapter 1

The FOC for the social planner problem after substituting the envelop theorem and steady state conditions was is given by:

\[
 r^*(1 - f(\alpha(c + 1))) - r^*(c + 1)\alpha f'(\alpha(c + 1)) - \frac{c}{f(\alpha(c + 1))\alpha + \alpha + c\alpha} \\
- \frac{\delta c\alpha(f(\alpha(c + 1)) + \alpha(c + 1)f'(\alpha(c + 1)) + \bar{r}c + \bar{r})}{(f(\alpha(c + 1))\alpha + \alpha + c\alpha)^2} = 0
\]

Simplifying the denominator of the last two terms we get:

\[
 r^*(1 - f(\alpha(c + 1))) - r^*(c + 1)\alpha f'(\alpha(c + 1)) - \frac{c}{\alpha(f(\alpha(c + 1)) + 1 + c)} \\
- \frac{\delta c(f(\alpha(c + 1)) + \alpha(c + 1)f'(\alpha(c + 1)) + \bar{r}c + \bar{r})}{\alpha(f(\alpha(c + 1)) + 1 + c)^2}
\]

Now adding the last two terms we get:

\[
 r^*(1 - f(\alpha(c + 1))) - r^*(c + 1)\alpha f'(\alpha(c + 1)) \\
- \frac{c[f(\alpha(c + 1)) + 1 + c + \delta f(\alpha(c + 1)) + \delta \alpha(c + 1)f'(\alpha(c + 1)) + \delta(\bar{r}c + \bar{r})]}{\alpha(f(\alpha(c + 1)) + 1 + c)^2}
\]

Now further simplifying by multiplying throughout by \( \alpha(f(\alpha(c + 1)) + 1 + c)^2 \), we get Equation 4 which implicitly defines the aggregate default rates under the social planner problem:
\[ r^* \alpha (1 - f(\alpha(c + 1)))(f(\alpha(c + 1)) + 1 + c^2) \]
\[ - r^*(c + 1)\alpha^2 f'(\alpha(c + 1))(f(\alpha(c + 1)) + 1 + c^2) \]
\[ - c(1 + \delta)f(\alpha(c + 1)) - \delta c\alpha(c + 1)f'(\alpha(c + 1)) - (c\delta(\bar{r}c + \bar{r}) + c \]
\[ + c^2) \]
The default rates under the non-cooperative and cooperative scenarios were derived in Equation 3 and Equation 4, respectively. Since the R.H.S of both equations equals zero we can equate them, simplifying gives us:

\[ r^*a \left(1 - f(a(c + 1))\right) \left(f(a(c + 1)) + 1 + c\right)^2 \]

\[ - \frac{r^*\bar{a}(1 - f(\bar{a}(c + 1)))f(\bar{a}(c + 1)) + 1 + c^2}{N} \]

\[ + \frac{c(c + 1)\delta(\bar{a})f'(\bar{a}(c + 1))}{N} - c(c + 1)\delta a'f'(a(c + 1)) \]

\[ + \frac{r^*(c + 1)(\bar{a})^2f'(\bar{a}(c + 1))(f(\bar{a}(c + 1)) + 1 + c^2}{N^2} \]

\[ - r^*(c + 1)a^2f'(a(c + 1))(f(a(c + 1)) + 1 + c^2) \]

\[ + c(1 + \delta)f(\bar{a}(c + 1)) - c(1 + \delta)f(a(c + 1)) = 0 \]

For ease of exposition we divide the resulting expression into four parts we get:

A: \[ r^*a \left(1 - f(a(c + 1))\right) \left(f(a(c + 1)) + 1 + c\right)^2 - \frac{r^*\bar{a}(1 - f(\bar{a}(c + 1)))f(\bar{a}(c + 1)) + 1 + c^2}{N} \]

B: \[ \frac{r^*(c + 1)(\bar{a})^2f'(\bar{a}(c + 1))(f(\bar{a}(c + 1)) + 1 + c^2}{N^2} - r^*(c + 1)a^2f'(a(c + 1))(f(a(c + 1)) + 1 + c)^2 \]

C: \[ \frac{c(c + 1)\delta(\bar{a})f'(\bar{a}(c + 1))}{N} - c(c + 1)\delta a'f'(a(c + 1)) \]
D: \( c(1 + \delta)f(\bar{a}(c + 1)) - c(1 + \delta)f(\alpha(c + 1)) \)

Now, we need to show that \( \bar{\alpha} > \alpha \), to prove Proposition 2B. We show this by employing the proof by contradiction method. Let \( \alpha \geq \bar{\alpha} \) then note that by Proposition B \( f'(.) > 0 \) so if \( \alpha \geq \bar{\alpha} \) then \( f(\alpha) \geq f(\bar{\alpha}) \) so \( f((c + 1)\alpha) \geq f((c + 1)\bar{\alpha}) \) so expression D is always non-positive. Given \( f''(.) > 0 \), then note \( f'(\alpha(c + 1)) > f'(\bar{\alpha}(c + 1)) \) and \( \alpha > \frac{\bar{\alpha}}{N} \) if \( \alpha \geq \bar{\alpha} \), so expression C is always strictly negative. Likewise, for expression B,

\[
B_{\sigma}(f(\alpha(c + 1)) + 1 + c)^2 \geq (f(\bar{\alpha}(c + 1)) + 1 + c)^2, \alpha^2 > \frac{\bar{\alpha}^2}{N^2} \] as long as non-zero lending levels \( (N>1) \) and by the assumption that \( f''(.) > 0 \) we know that \( f'(\alpha(c + 1)) \geq f'(\bar{\alpha}(c + 1)) \). Hence, expression C is also always negative if \( \alpha \geq \bar{\alpha} \). However the sign of expression A is indeterminate because on one hand \( 1 - f(\alpha(c + 1)) \leq 1 - f(\bar{\alpha}(c + 1)) \) but on the other hand \( (f(\alpha(c + 1)) + 1 + c)^2 \geq (f(\bar{\alpha}(c + 1)) + 1 + c)^2 \) and \( \alpha > \frac{\bar{\alpha}}{N} \).

Therefore to complete the proof we need another assumption, i.e., \( A \neq B + C + D \). If this is so, then \( \alpha \geq \bar{\alpha} \) is not feasible as the RHS of equation 3 equals zero, so it must be that \( \bar{\alpha} > \alpha \) and hence \( f((c + 1)\bar{\alpha}) > f(\alpha(c + 1)) \), i.e., higher default rates due to the presence of intra-firm competition. Unlike the proof of Proposition 2A, this proof is not elegant and relies on an additional assumption. Nevertheless, to verify these results the model was calibrated with reasonable parameter estimates and numerical methods were
used to solve for the equilibrium default rates implied by Equation 3 and 4, results are shown at the end of Section 4.3.
Appendix E: Poultry Farmer Survey Questionnaire

A stacked survey methodology was adopted to gain maximum information about the poultry industry at minimum cost. Approximately 50 subjects, belonging to different categories (parent stock companies and hatcheries, chick and broiler farmers, middlemen and retailers) involved in the poultry value chain, were interviewed by a professional marketing research company called The Learning Organization (TLO) under my supervision between August-October 2015. The questions for structured interviews, usually lasting for approximately 1-2 hours, are provided below along with the relevant subject headings.

1-Business Model and the Poultry Value Chain

- Briefly describe your role in the poultry value chain?
- Who are the most powerful players in the chick and broiler value chain?
- What is the reason for engaging intermediary in the value chain instead of direct dealing with hatchery/retailer?
- What is the commission structure of middlemen in the value chain?

2-Demand/Supply Trends and Determinants

- What are the major trends of demand for chicken in Pakistan?
• What are the major determinants of supply (production) of chicks and broiler in Pakistan?
• How do individual farmers make their decisions about when/how much to supply in a given time period?
• What are the reasons for overproduction?
• Are the market dynamics for chick and broiler different in other regions of Pakistan? Yes/No? Why?

3-Poultry Data related to Demand and Supply

• What are the main cost components in the production of chick and broiler?
• Do you think that cost components have shown considerable volatility over the past five years? If yes than why and which components?
• What are the main cost components vis-à-vis the selling and marketing expenses of chick and broiler? Do you think that selling/marketing costs have changed considerably over the past 5 years? If yes than why?

4-Price determination and Communication

• How are farm gate prices set in the chick and broiler industry?
• How are the prices communicated to various stakeholders?
• Is there any mechanism to ensure that everyone is selling chick and broiler at the circulated prices?
5-Price Volatility

- What do you think are the possible reasons behind the volatility in prices of chick and broiler?
- What is the impact of price volatility on your business?
- What is the possible impact of price volatility on other participants in the value chain (e.g. feed mills, breeding farms, broiler farms, retailers, final consumer)?
- Who do you think gains the most in the value chain due to these price fluctuations?
- Who do you think loses the most in the value chain due to these price fluctuations?
- What measures can be taken to stabilize the prices of poultry products?
Appendix F: Derivation of the System of Linear Price Equations

In order to calibrate the theoretical model presented in Section 4, we use a power function to represent the convex cost functions of poultry farmers and a linear function to capture the retail demand for broilers\textsuperscript{142}. More specifically we employ:

- A convex cost function of chick farmers at time $t$: $C_1(q^c_t) = (q^c_t)^\alpha$ where $\alpha > 1$
- A convex cost function of broiler farmers at time $t$: $C_2(q^c_t) = (q^c_t)^\beta$ where $\beta > 1$
- A linear retail demand function for broilers at time $t$: $Q^B_t = a - bp^B_t$ where $a > 0$ represents the extent (or maximum capacity) of a given retail demand and $b > 0$ represents the sensitivity of demand to broiler prices.

Given these primers, recall that the derivation of broiler price dynamics under the naïve expectations hypothesis yielded the following difference equation:

$$p^B_t = F^{-1}\left(\frac{kN_3}{N_3} (C_2')^{-1}(kp^B_{t-2} - \omega^C_{t-2})\right)$$

Substituting in the above-mentioned functional forms and performing some algebraic manipulations yields:

\textsuperscript{142} Since the domain of cost functions is strictly positive by definition, therefore all power functions are convex functions. Likewise, both power functions and linear functions have a well-defined inverse, note that since prices are always positive, the range of the inverse function is also the real line.
Similarly the difference equation for broiler prices was given by:

$$\omega^c_t = kp^B_{t-1} - C^2_t \left( \frac{N_1}{N_2} \left( \frac{C^c_t}{C^c_1} \right)^{-1} \omega^c_{t-1} \right)$$

Substituting in the relevant functional forms, and performing some algebraic manipulations gives us the following price dynamic for chick prices:

$$\omega^c_t = kp^B_{t-1} - \left( \frac{N_1 \beta}{N_2} \right)^{\beta-1} \left( \frac{\omega^c_{t-1}}{\alpha} \right)^{\beta-1}$$

In the special case of quadratic cost functions ($\alpha = \beta = 2$), the difference equations of broiler and chick prices can be reduced to the following system of linear equations:

$$p^B_t = \frac{a}{b} - \frac{N_2 k}{N_3 b} \left( \frac{kp^B_{t-2} - \omega^c_{t-2}}{\beta} \right)^{\frac{1}{\beta-1}}$$

$$\omega^c_t = kp^B_{t-1} - \frac{N_1}{N_2} \omega^c_{t-1}$$
Appendix G: Unique Steady-State of the Time Delay System

Again in an equilibrium or steady state we have $p_t^B = p_{t-3}^B = p_{t-6}^B = p^B$ and $\omega_t^C = \omega_{t-3}^C = \omega_{t-6}^C = \omega^C$. Substituting into the system of equations we get:

$$p^B = \frac{a}{b} - \frac{N_2 k}{N_3 b} \left( \frac{kp^B}{\beta} - \omega^C \right)^{\frac{1}{\beta-1}}$$

$$\omega^c = kp^B - \left( \frac{N_1 \beta}{N_2} \right)^{\frac{\beta-1}{\alpha-1}} \left( \frac{\omega^C}{\alpha} \right)^{\frac{\beta-1}{\alpha-1}}$$

From the chick price equation we get:

$$p^B = \frac{1}{k} \left( \omega^c + \left( \frac{N_1 \beta}{N_2} \right)^{\frac{\beta-1}{\alpha-1}} \left( \frac{\omega^C}{\alpha} \right)^{\frac{\beta-1}{\alpha-1}} \right)$$

Substituting the above expression into the broiler price equation and simplifying yields:

$$\omega^c + \left( \frac{N_1 \beta}{N_2} \right)^{\frac{\beta-1}{\alpha-1}} \left( \frac{\omega^C}{\alpha} \right)^{\frac{\beta-1}{\alpha-1}} = \frac{ka}{b} - \frac{N_2 k^2}{N_3 b} \left( \omega^c + \left( \frac{N_1 \beta}{N_2} \right)^{\frac{\beta-1}{\alpha-1}} \left( \frac{\omega^C}{\alpha} \right)^{\frac{\beta-1}{\alpha-1}} - \omega^C \right) \left( \frac{1}{\beta} \right)^{\frac{1}{\beta-1}}$$

$$\omega^c + \left( \frac{N_1 \beta}{N_2} \right)^{\frac{\beta-1}{\alpha-1}} \left( \frac{\omega^C}{\alpha} \right)^{\frac{\beta-1}{\alpha-1}} + \frac{N_1 k^2 \beta}{N_3 b} \left( \frac{\omega^C}{\alpha} \right)^{\frac{1}{\alpha-1}} \left( \frac{1}{\beta} \right)^{\frac{1}{\beta-1}} - \frac{ka}{b} = 0$$

This equation is non-linear as long as ($\alpha = \beta \neq 2$). In order to study the characteristics of the fixed point of this equation we can decompose it into a function $f(\omega^c) = \omega^c +$
\[
\left(\frac{N_1 \beta}{N_2}\right)^{-1} \left(\frac{\omega^c}{\alpha}\right)^{-1} + \frac{N_1 k^2 \beta}{N_3 b} \left(\frac{\omega^c}{\alpha}\right)^{-1} \left(\frac{1}{\beta}\right)^{-1},
\]
where the domain of \(\omega^c\) is the positive real line and a constant \(C = \frac{ka}{b}\), where \(0 < C < \infty\) by definition of the parameters in the model. Obviously at the solution \(f(\omega^c) = C\).

Clearly, \(f(0) = 0\) and \(f(\infty) = +\infty\). Note that \(f'(\omega^c) = 1 + \frac{N_1 \beta}{N_2} \left(\frac{\omega^c}{\alpha}\right)^{-1} \left(\frac{1}{\beta}\right)^{-1} + \frac{N_1 k^2 \beta}{(\alpha-1)N_3 b} \left(\frac{\omega^c}{\alpha}\right)^{-1} \left(\frac{1}{\beta}\right)^{-1} > 0\), since \(\beta > 1\) and \(\alpha > 1\) by definition and all other model parameters are strictly positive. Therefore, given \(f(\omega^c)\) is a strictly increasing function on its domain, we can use the single crossing property to conclude that \(f(\omega^c)\) intersects \(C\) at a single point. Given the unique steady state \(\omega^c\), we can compute the corresponding equilibrium broiler price \(p^B\). Note, that we do not consider economically irrelevant steady states, i.e., when \(\omega^c\) and/or \(p^B\) are less than zero, since prices are positive by definition. The actual steady states are only implicitly defined and cannot be expressed as a function of the model parameters. Nevertheless, actual values can be computed via numerical methods given suitable model calibrations.
Appendix H: Eigenvalues & Stability of the Linear Time-Delay System

The special case of a system of linear time-delay difference equations is given by:

\[
p_t^B = \frac{a}{b} - \frac{N_2 k^2}{2bN_3} p_{t-6}^B + \frac{N_2 k}{2bN_3} \omega_{t-6}^C
\]

\[
\omega_t^C = kp_{t-3}^B - \frac{N_1}{N_2} \omega_{t-3}^C
\]

It is straightforward to notice that this is a system with sixth-order difference equations and two state variables. In order to study the stability and qualitative behavior of the system we can rewrite it as a system of first order difference equations with a dimension of 2x6. Whereby, n-1 new variables are defined to represent each higher order difference term along with a new system constant C. Therefore, let \( x_t^i = p_{t-i}^B \) and \( y_t = \omega_{t-1}^C \) for \( i = 1 \) to 6.

\[
\begin{bmatrix}
p_t^B \\
\omega_t^C \\
x_t^1 \\
y_t^1 \\
x_t^2 \\
y_t^2 \\
x_t^3 \\
y_t^3 \\
x_t^4 \\
y_t^4 \\
x_t^5 \\
y_t^5
\end{bmatrix}
= \begin{bmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \frac{N_2 k^2}{2bN_3} & \frac{N_2 k}{2bN_3} & x_t^1 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & y_t^1 \\
0 & 0 & 0 & 0 & k & \frac{N_1}{N_2} & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & x_t^2 \\
1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & y_t^2 \\
0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & x_t^3 \\
0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & y_t^3 \\
0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & x_t^4 \\
0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & y_t^4 \\
0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & x_t^5 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & y_t^5 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & x_t^6 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & y_t^6
\end{bmatrix} + C
\]
It is easy to notice that the augmented system comprises of first order difference equations, i.e., after making the appropriate substitutions we get the relevant price equations and 10 identities:

\[
\begin{bmatrix}
  p_t^B \\
  \omega_t^C \\
  p_{t-1}^B \\
  \omega_{t-1}^C \\
  p_{t-2}^B \\
  \omega_{t-2}^C \\
  p_{t-3}^B \\
  \omega_{t-3}^C \\
  p_{t-4}^B \\
  \omega_{t-4}^C \\
  p_{t-5}^B \\
  \omega_{t-5}^C
\end{bmatrix}
= \begin{bmatrix}
  0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & N_2 k^2 / 2bN_3 & N_2 k \\
  0 & 0 & 0 & k & N_1 / N_2 & 0 & 0 & 0 & 0 & 0 \\
  0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
  0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
  0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\
  0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
  0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\
  0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\
  0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\
  0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1
\end{bmatrix}
\begin{bmatrix}
  p_{t-1}^B \\
  \omega_{t-1}^C \\
  p_{t-2}^B \\
  \omega_{t-2}^C \\
  p_{t-3}^B \\
  \omega_{t-3}^C \\
  p_{t-4}^B \\
  \omega_{t-4}^C \\
  p_{t-5}^B \\
  \omega_{t-5}^C
\end{bmatrix}
+ C
\]

For notational simplicity, let \(X_t\) denote the LHS vector of variables and \(A\) represent the transition matrix, then the model can be succinctly written as a first order system: \(X_t = AX_{t-1} + C\). It is well known, that eigenvalues of the matrix \(A\) will determine the behavior of the original time-delay system. Note that in equilibrium \(X_t = X_{t-1} = X\), substituting into the augmented first order system and simplifying we get: \(X = (I - A)^{-1} C\). It is easy to show that \((I - A)^{-1}\) is always invertible and thus the augmented system has a unique fixed point just like the original time-delay system.

Due to the large dimension of the system matrix \(A\), formulating and factorizing the associated characteristic equation is not feasible. Therefore, we use MATLAB to
calculate eigenvalues under suitable model calibrations, these calibrations are identical to ones used for numerical simulations of the baseline model in Section 5.3, i.e., \( k = 0.95, b = 0.45, \alpha = 90, N_1 = 10, N_2 = 11, \) and \( N_3 = 12. \) The eigenvalues are: \( \lambda_{1,2} = -0.9392 \pm 0.3434i, \lambda_{3,4} = 0.1722 \pm 0.9851i, \lambda_{5,6} = 0.7670 \pm 0.6417i, \lambda_{7,8} = -0.2184 \pm 0.3784i, \lambda_{9,10} = -1.4733e-06 \pm 2.5519e-06i, \lambda_{11} = 0.4367 \) and \( \lambda_{12} = 2.9467e-06 \) respectively. Qualitatively, similar eigenvalues are obtained for within the domain of \( k. \)

Although, the above-mentioned analysis has been performed for the special case of our time-delay model, i.e., a linear system when \( \alpha = \beta = 2. \) This method can be followed to study the local stability of the non-linear systems as well, i.e., when \( \alpha = \beta \neq 2, \) by replacing the coefficient or system transition matrix by the Jacobian of the resulting first order system so as to linearize the non-linear system around the fixed point.\(^{143}\) Again, for sake of brevity, we choose not to pursue this line of inquiry further since it entails numerical computation of the fixed point of the non-linear system (please refer to Appendix H) along with other detailed computations.

\(^{143}\) Note that for linear systems, local stability and asymptotic stability are equivalent notions. While for non-linear system we can only study the local behavior of the system analytically and need to use numerical simulations to investigate the global behavior.
Appendix I: Stability of Linear Time Delay System independent of Time-Delays

Derivation of delay-dependent stability criterion for time-delay systems is possible in very few cases, usually for very simple systems. However, stability criterion independent of delay can be easily derived for most time-delay systems. Hale et al. (1989) have provided necessary and sufficient conditions for the asymptotic stability of time-delay systems independent of delay:

Let $\mathbf{x}$ represent a vector of endogenous state variables with a fixed time-delay $d$ and related coefficient matrix $A$ and $A_d$, such that the resulting system of retarded differential equations is given by:

$$
\dot{\mathbf{x}} = A\mathbf{x} + A_d\mathbf{x}(t-d).
$$

This system is asymptotically stable, independent of delay if

$$
\text{Re } |\lambda(A + A_d)| < 0 \text{ under standard normality conditions.}
$$

It is well known that time-delay difference equations with a fixed delay are just the discrete time analogue of retarded differential equations, and can be readily converted into the latter, the resulting theorem for difference equations is given by:

$$
\dot{\mathbf{x}} = A\mathbf{x} + A_d\mathbf{x}(t-d).
$$
\( \Delta x_t = Ax_{t-1} + A_d x(t - d) \). This is system is asymptotically stable, independent of delay if \( \text{Re} \; |\lambda(A + A_d)| < 1 \) under standard normality conditions.\(^{144}\)

Applying this theorem to time-delay system under study in this paper, we get:

\[
\begin{bmatrix}
\Delta p^B_t \\
\Delta \omega^C_t
\end{bmatrix} =
\begin{bmatrix}
-1 & 0 \\
0 & -1
\end{bmatrix}
\begin{bmatrix}
p^B_{t-1} \\
\omega^C_{t-1}
\end{bmatrix} +
\begin{bmatrix}
k \\
\frac{N_1}{N_2}
\end{bmatrix}
\begin{bmatrix}
p^B_{t-3} \\
\omega^C_{t-3}
\end{bmatrix} +
\begin{bmatrix}
-N_2 \frac{k^2}{2bN_3} & N_2 \frac{k}{2bN_3} \\
0 & 0
\end{bmatrix}
\begin{bmatrix}
p^B_{t-6} \\
\omega^C_{t-6}
\end{bmatrix} +
\begin{bmatrix}
a \\
b
\end{bmatrix}
\]

Following Hale et al. (1989), we need to look at the eigenvalues of the following matrix in order to determine the asymptotic stability of the abovementioned system independent of time delay:

\[
\lambda(A + A_d) =
\begin{bmatrix}
-1 - \frac{N_2 k^2}{2bN_3} & \frac{N_2 k}{2bN_3} \\
k & -1 - \frac{N_1}{N_2}
\end{bmatrix}
\]

The corresponding characteristic equation is given by:

\[
(1 + \frac{N_2 k^2}{2bN_3} + \lambda)(1 + \frac{N_1}{N_2} + \lambda) - \frac{N_2 k^2}{2bN_3} = 0
\]

Multiplying out and collecting terms we get:

\[
\lambda^2 + \lambda \left(2 + \frac{N_1}{N_2} + \frac{N_2 k^2}{2bN_3}\right) + 1 + \frac{N_1}{N_2} + \frac{N_1 k^2}{2bN_3} = 0
\]

\(^{144}\)Simply subtract \( x_{t-1} \) from both sides, such that we have the change in \( x \) on the left hand side, see Vas (2016) for details. Note that in contrast to continuous time whereby the eigenvalues are the exponent in the symbolic dynamic of the system, in discrete time the eigenvalues are the base of the exponent in the symbolic dynamics. Therefore, asymptotic stability is discrete time systems is achieved if the absolute value of the eigenvalue is less than 1, i.e., all eigenvalues are within the unit circle.
Now, using the quadratic root formula: \( \frac{-b \pm \sqrt{(b^2 - 4ac)}}{2a} \), where \( b = 2 + \frac{N_1}{N_2} + \frac{N_2k^2}{2bN_3} \), \( a = 1 + \frac{N_1^2}{N_2} + \frac{N_2k^2}{2bN_3} \) and \( a = 1 \). It is straightforward to notice that \( \frac{|-b|}{2a} > 1 \), since \( \frac{N_1}{N_2} \) and \( \frac{N_2k^2}{2bN_3} \) are non-zero positive numbers by definition of the parameters. Similarly, simplifying the expression \( (b^2 - 4ac) \) we get: \( \frac{N_1^2}{N_2} + \frac{N_2k^4}{4b^2N_3^2} + \frac{k^2(2N_2-N_1)}{bN_3} \), this expression is also strictly positive by definition of the parameters\(^{145} \).

We know with certainty that that absolute value of \( \lambda_1 = \frac{-b}{2a} - \frac{\sqrt{(b^2 - 4ac)}}{2a} \) is greater than 1, since both \( \frac{b}{2a} \) and \( \frac{\sqrt{(b^2 - 4ac)}}{2a} \) are positive, while \( \frac{|b|}{2a} > 1 \) by definition. For our purposes it suffices to note that \(|\lambda_1| > |\lambda_2| \), where \( \lambda_2 = \frac{-b}{2a} + \frac{\sqrt{(b^2 - 4ac)}}{2a} \). Because the asymptotic behavior of the system is determined by the dominant or largest eigenvalue and it is well known that the underlying system is asymptotically unstable if the absolute value of the dominant eigenvalue is greater than 1. Therefore, we conclude that the underlying system is asymptotically unstable independent of time-delays.

Note that in addition to \(|\lambda_1| > 1\), \(\lambda_1\) is also negative, consistent with oscillatory diverging behavior, while the sign of \(\lambda_2\) depends on the parameter values. Likewise, depending on the parameter values either \(|\lambda_1| > 1 > |\lambda_2|\) which corresponds to a saddle point or an unstable explosive system \(|\lambda_1| > |\lambda_2| > 1\). In order to get a better idea of the behavior of

\(^{145}\) Recall that the \( N_i \) was used to measure relative bargaining power of the ith counterparty and assumed to be such that the ratio of any two \( N_i \) is within reasonable bounds such that considerations of imperfect competition do not arise. Therefore \( 2N_2 < N_1 \) is not feasible given our model. Also note that based on surveys data assuming \( N_1 < N_2 \).
the underlying model without the effects of time-delays on system dynamics, we compute the eigenvalues using model calibrations for the baseline case, i.e., \( k = 0.95, b = 0.45, a = 90, N_1 = 10, N_2 = 11 \) and \( N_3 = 12 \). The resulting eigenvalues are \( \lambda_1 = -2.70 \) and \( \lambda_2 = -0.96 \), consistent with a saddle-point, whereby the system is best characterized by oscillatory divergence away from the equilibrium or explosion in the direction of \( \lambda_1 \) and oscillatory convergence towards equilibrium in the direction of \( \lambda_2 \). Also, note that \( \lambda_2 \) is approximately equal to \(-1\) in the baseline case, indicative of the borderline case of perpetual oscillations around the equilibrium. Of course, the baseline model independent of time-delay is also asymptotically unstable due to the effect of the dominant eigenvalue.
Appendix J: Bifurcation diagram MATLAB Routine

In order to create a bifurcation diagram, a researcher needs to code three key routines. First, forward solve the system of difference equations for different values of the bifurcation parameter and save the results. Second, truncate the resulting trajectories at a suitable point (often arbitrary and based on the researcher’s judgment) to focus on the limiting behavior of the system. Lastly, plot the truncated trajectories against the bifurcating parameter, the resultant MATLAB code is:

```matlab
clear all
close all
clc
A=2;%alpha in appendix-F%
B=2;%beta in appendix-F%
n1=10;
n2=11;
n3=12;
a=90;
b=0.5;
Npre = 50; Nplot = 200;
chickprice = zeros(Nplot,1);
broilerprice=zeros(Nplot,1);
for k = 0.075:0.0001:1,
    chickprice(1) = 20;
    chickprice(2) = 25;
    chickprice(3) = 30;
    chickprice(4) = 30;
    chickprice(5) = 27;
    chickprice(6) = 20;
    broilerprice(1) = 100;
    broilerprice(2) = 85;
    broilerprice(3) = 79;
```
broilerprice(4) = 70;
broilerprice(5) = 72;
broilerprice(6) = 80;
for t = 7:Nplot,
    chickprice(t)= k*broilerprice(t-3) - ((n1*B/n2)^(B-1))*(chickprice(t-3)/A)^(B-1)/(A-1));
    broilerprice(t)= a/b-(n2*k)/(n3*b)*((k*broilerprice(t-6)/B-chickprice(t-6)/B)^{1/(B-1)});
end,
subplot(211)
    plot(k*ones(Nplot-Npre,1),real(chickprice(Npre:Nplot-1)), '.','markersize', 3);
    hold on
subplot(212)
    plot(k*ones(Nplot-Npre,1),real(broilerprice(Npre:Nplot-1)), '.','markersize', 3);
    hold on;
end,
xlabel('k'); ylabel('Price');
set(gca, 'xlim', [0 1]);
hold off;
### Appendix K: Summary of KSE performance indicators from 2000-2011

<table>
<thead>
<tr>
<th>Year</th>
<th>Market Capitalization (Pak Rs)</th>
<th>Market Capitalization (% of GDP)</th>
<th>Stocks Traded (% of GDP)</th>
<th>S&amp;P Global (Price Change Index)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>6,581,370,000</td>
<td>8.9</td>
<td>44.6</td>
<td>-16.7</td>
</tr>
<tr>
<td>2001</td>
<td>4,943,970,000</td>
<td>6.8</td>
<td>17.2</td>
<td>-32.8</td>
</tr>
<tr>
<td>2002</td>
<td>10,199,740,000</td>
<td>14.1</td>
<td>36</td>
<td>112</td>
</tr>
<tr>
<td>2003</td>
<td>16,578,610,000</td>
<td>19.9</td>
<td>80</td>
<td>50.4</td>
</tr>
<tr>
<td>2004</td>
<td>29,002,180,000</td>
<td>29.6</td>
<td>75.4</td>
<td>20.7</td>
</tr>
<tr>
<td>2005</td>
<td>45,936,760,000</td>
<td>41.9</td>
<td>128.6</td>
<td>58.5</td>
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<tr>
<td>2006</td>
<td>45,517,640,000</td>
<td>35.6</td>
<td>99.3</td>
<td>1.3</td>
</tr>
<tr>
<td>2007</td>
<td>70,262,230,000</td>
<td>49.1</td>
<td>70.2</td>
<td>41.7</td>
</tr>
<tr>
<td>2008</td>
<td>23,490,665,415</td>
<td>14.3</td>
<td>33.2</td>
<td>N/A</td>
</tr>
<tr>
<td>2009</td>
<td>33,238,531,669</td>
<td>20.5</td>
<td>14.5</td>
<td>56.7</td>
</tr>
<tr>
<td>2010</td>
<td>38,168,586,546</td>
<td>21.6</td>
<td>7.3</td>
<td>15.3</td>
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<tr>
<td>2011</td>
<td>32,763,702,675</td>
<td>15.6</td>
<td>4.8</td>
<td>-18.8</td>
</tr>
<tr>
<td>Average</td>
<td>29,723,665,525</td>
<td>23.16</td>
<td>50.93</td>
<td>26.21</td>
</tr>
</tbody>
</table>