Essays on a City's Assets: Agglomeration Economies and Legacy Capital

DISSERTATION

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Abstract

This dissertation presents five essays dealing with the utilization and abandonment of a city's assets, in particular two key assets: agglomeration economies and legacy capital.

The first essay traces out the causes and effects of agglomeration economies by disentangling economies of agglomeration. It disentangles amenity and productivity effects of agglomeration; it decomposes aggregate scale effects into agglomeration factors of interest to policy makers; and it estimates own effects and spillovers to neighbors. It proposes a spatial simultaneous equations model in a spatial equilibrium framework with three agents – worker consumers and producers of traded goods and housing. Results for Ohio counties estimate economies resulting from population size, agglomeration causes, and public service quality and cost on each of the three agents in own and neighboring counties.

The second essay theoretically models the abandonment and reuse of legacy capital in the process of industrial restructuring. It aims to identify the conditions for abandonment and the factors that determine the length of abandonment. The model is based on investment theory and game theory. It shows that abandonment is impacted by conversion costs of legacy capital, the rate of growth of industries involved in the restructuring, and policy variables such as tax rate.

The third essay empirically verifies the theoretical model developed in the second essay, using data of industrial and commercial properties (ICPs) in the Cleveland city-region in Ohio. It shows that in declining industries or regions, ICPs experience tax delinquency of longer duration and are more likely to be abandoned than elsewhere. Also, ICPs with higher conversion costs are more likely to experience longer spells of tax delinquency and are more likely to be abandoned

than others. Abandoned ICPs are spatially concentrated either as a result of negative spillovers or shared history.

The fourth essay theoretically models the externalities involved in the abandonment and conversion of abandoned properties, and suggests a Pigouvian subsidy to encourage conversion and to restore the social optimum. As the size of the externality depends on the level of abandonment, a socially optimal subsidy is derived as a function of a city's share of abandoned to total capital. The paper also models land use conversion as function of ownership fragmentation and compares the timing of conversion for the single and fragmented ownership case.

The last essay empirically examines how legacy capital and agglomeration economies affect urban growth. This essay employs a series of regressions to investigate the relationship, using a sample of central cities in Metropolitan Statistical Areas of the U.S. It shows that for economies facing deindustrialization, a speedy reuse of legacy capital encourages economic resurgence; sustained abandonment reduces growth; and agglomeration economies facilitate urban growth or retard urban decline.

Dedication

This document is dedicated to my family.

Acknowledgments

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Chapter 1: Introduction

Rising urbanization and accompanying rural urban migration have led to unprecedented urban growth, so that now more than half of the world's population lives in urban areas. This has also meant that most urban areas individually have grown, sometimes at double digit rates, particularly in the developing world. Given this tide of urban growth, it is easy to forget that cities also decline, and that historically, decline has been as much part of the urban history as growth. Nowhere in the United States, is this more evident than in parts of the Northeast and in Ohio in particular. Cities such as Cleveland, Toledo or Youngstown are in the news often, as over the past 50 years they have lost much of their industrial base, followed by population decline, and abandonment of industrial or residential buildings. Putting existing buildings and infrastructure to new use, is often difficult, as cities are burdened by numerous legacies, including an antiquated infrastructure that is difficult to modernize, industrial sites that are difficult to convert, institutions that are unwilling to adapt, and fragmented property rights that make a fresh start difficult. Faced with decline and limited demand for abandoned property, planners increasingly must deal with the problem of how to convert urban land into parks, rather than the more familiar problem of putting agricultural land to urban use.

Large metropolitan areas are not immune from these problems. While their large size provides legacy benefits in the form of agglomeration economies and a diversified economy conducive to business creation, their central cities in particular suffer from intra-urban competitive disadvantages, relative to their suburbs.

This dissertation deals with problems associated with urban growth and decay, and in particular the management of transition – from one economic structure to another, or from one set of land and building uses to another. The ease of such a transition is seen to depend on two key city assets – its legacy capital and the level of agglomeration economies inherited from the past. Legacy capital in the dissertation usually refers to immobile and costly to convert capital such as buildings and infrastructure, though may also include non-physical assets, such as obsolete and fragmented property rights, outdated legal and regulatory systems, and difficult to change institutions. Cities faced with external shocks and the loss of their economic base, must find new uses for their capital. This is easier for some types of capital than others, and we show that for industrial and manufacturing capital in particular, new uses are most difficult to find, and conversion to new uses is the most costly. Hence, these cities face the most difficult path towards recovery.

Agglomeration economies and diseconomies are another asset, in that the size of an urban economy to some extent determines the productivity of its firms, and the amenities or quality of life of its residents. A greater size generally is recognized to allow the greater sharing of facilities, it generates a greater diversity of goods and services, it reduces cost through greater competition, and it raises capacity utilization through a pooling of risks. Larger areas therefore, should be better able to withstand external shocks, and to make the transition to a new economic base.

The dissertation will explore issues related to the two types of assets and their impact on growth and decline in five essays. Of these two involve only a theoretical model without empirical testing. Of the remaining three, two include both theoretical and empirical modeling and one is limited to an empirical study. Of the theoretical models several have a static partial or general equilibrium framework. However, this still makes possible dynamic inferences. Typically, it will take time for an economy to react to an external shock, and the change in an equilibrium position tells us something about a future path of the economy.

Chapter 2 is provides a spatial general equilibrium model and empirical analysis of agglomeration economies and diseconomies. Agglomeration economies are a central theme of spatial economics. Geographic agglomeration of economic activities creates a favorable environment for firms through abundant labor pooling, large home markets, and rich non-traded inputs such as a high quality of infrastructure. Similarly, consumers are affected by amenities and disamenities created by agglomeration such as large markets, infrastructure, congestion, and pollution. Without these economies of agglomeration, there would be no cities or economic clusters, at least not in the absence of productivity variations over space. However, agglomeration economies so far have been modeled only in the most rudimentary fashion. Often, they focus only on productivity effects and leave out equally important amenity impacts; and most of the empirical studies proxy agglomeration effects only through the aggregate population, rather than other scale related variables. This aggregation makes it impossible to differentiate between positive and perhaps equally important negative effects. It also leaves the model short of policy variables with which to study ways to improve a city's competitive position or to react to external shocks such as the deindustrialization mentioned earlier. Another problem is that even though agglomeration economies represent an externality, spatial spillover effects are generally not well modeled and cannot be associated with particular agglomeration factors. However, this is essential to studying the relationship between central city and suburb, or metropolitan area and rural hinterland.

This study disentangles agglomeration economies in three dimensions: impacted agents, impacting factors, and spatial dependence. It proposes a spatial simultaneous equations model in a spatial equilibrium framework with three agents – worker consumers and producers of traded goods and housing. Results for Ohio counties estimate economies resulting from population size, agglomeration causes, and public service quality and cost on each of the three agents in own and neighboring counties.

This research provides an overall framework within which to study the effect of external shocks, and policies designed to advance growth or mitigate decay. While the model is static, a city's dynamics are in large part determined by its changing equilibrium position as a result of an external shock. The model includes a number of variables directly related to policy instruments available to the planner, including variables related to infrastructure and service quality and cost. While there is as yet no direct variable that differentiates capital according to its conversion cost, this can be included in the future, to tie the model more directly to the overall theme of this dissertation.

Chapter 3 theoretically models the abandonment and reuse of legacy capital in the process of industrial restructuring. When one industry declines and another rises, the uses of legacy capital must change as capital is transferred in line with the transition from one industry to another. Sometimes, however, this conversion of legacy capital incurs conversion costs and in turn leads to a period of abandonment. This essay proposes a theoretical model with a dynamic strategy played by individual actors to show how abandonment takes place as part of the conversion and re-use of legacy capital.

The model identifies the conditions for abandonment and the factors that determine the length of abandonment during a process of industrial restructuring when one sector declines and another slowly grows. It shows that abandonment is impacted by the amount of conversion costs for the conversion of legacy capital, such as the cost of remodeling and rebuilding. The greater these costs, the longer the delay in a new firm's entry and the longer a property's duration of abandonment. Second, the rate of growth in the incoming sector and the rate of decline in the outgoing sector impact these outcomes. The abandonment period will become longer, the lower the rate of growth in the new industry and the higher the rate of decline in the outgoing industry. Third, policy variables also influence the outcome. The abandonment period of the property will become longer, the higher the tax rate, and the longer the maximum period of tax delinquency. The chapter is theoretical only, but it represents the basis in Chapter 4 for an empirical study of tax delinquency and abandonment decisions, using Cleveland parcel data.

This chapter is relevant because of its novel approach to explaining the presence and optimality of abandonment. Abandonment of legacy capital is modeled as an outcome of a trading game between an incoming firm, an outgoing firm, and the local government, where the three agents interact to maximize own profits or proceeds. The ideas in this chapter open a wide array of future research opportunities related to micro-studies of land use and property conversion and abandonment, which are central to modeling and understanding the options available to declining cities. Cities such as Youngstown have experienced a population decline of 50 percent or more, and in the absence of newly emerging industries, have struggled to maintain their infrastructure, to reduce the aerial footprint of the city, to convert neighborhoods to parks and recreation and to otherwise adjust their cities. There is still little theory and empirical study surrounding this process and optimal policies to mitigate its negative effects.

Chapter 4 empirically verifies the theoretical model developed in Chapter 3, using data of industrial and commercial properties (ICPs) in a representative old industrial region, the Cleveland city-region in Ohio. Specifically this essay explains which ICPs have abandonment potential, and what factors determine their vulnerability to economic challenges. Property tax arrearage is used as an indicator of vulnerability of ICPs to economic challenges, as with some studies on housing abandonment. In other words, a property with a long tax delinquency spell is considered vulnerable to an economic downturn and to have abandonment potential. We employ data on property characteristics and taxes obtained from a vast database: Northeast Ohio Community and Neighborhood Data for Organizing (NEO CANDO).

This essay empirically verifies that an ICP of a fast declining industry and/or region is more likely to experience longer spells of tax delinquency and is also more likely to be abandoned than an ICP of a growing or at least slowly declining industry and region. Faced with the decline of an industry and region, an ICP is either abandoned or converted from one use to another, incurring conversion costs. ICPs with higher conversion costs experience longer tax delinquency spells and are more likely to be abandoned than others. Abandoned ICPs are spatially concentrated in specific zones, either due to shared history of industrial clustering or negative spillovers from abandonment.

The chapter is relevant within the general context of the abandonment literature. Most of it, both theoretical models and empirical results are confined to the residential property market. This research shows that an external shock in the form of deindustrialization has an impact on the length of tax delinquency and likelihood of abandonment, as does the level of conversion costs. The results of this chapter also are relevant within the context of this dissertation, in that they provide an example of possible micro-empirical studies of city decay and accompanying abandonment and conversion of building and land use.

Chapter 5 deals with negative spillovers from abandoned capital. Abandoned capital results in disamenities for residents in surrounding neighborhoods and also leads to a decline in productivity of remaining firms. Private agents do not take into account abandonment externalities when making decisions about the reuse or potential abandonment of legacy property and hence, unfettered markets lead to too much abandonment, longer periods of abandonment, and too little conversion than is socially suboptimal. Correction of this market failure requires government intervention to facilitate the timely conversion of properties to new uses.

This essay models the externalities involved in the abandonment and conversion of abandoned properties, and suggests a Pigouvian subsidy to encourage conversion and to restore the social optimum. As the size of the externality depends on the level of abandonment, a socially optimal subsidy is derived as a function of a city’s share of abandoned to total capital. The paper also models land use conversion as function of ownership fragmentation and compares the timing of conversion for the single and the fragmented ownership case.

Chapter 6 is an empirical survey that examines how legacy capital and agglomeration economies affect urban growth or decline. Different from the empirical investigation in Chapter 2, here we consider only central cities. Chapter 3 has shown that conversion cost slows the speed of adjustment. This leads to the prediction: For economies facing deindustrialization, a speedy reuse of legacy capital encourages economic resurgence; and sustained abandonment reduces growth. Chapter 2 has shown that agglomeration economies lead to amenity and productivity gains. This leads to the prediction that larger city size may facilitate urban growth or retard urban decline. This essay examines whether these theoretical predictions are true, using a sample of 326 (and in one case, 36) central cities in Metropolitan Statistical Areas of the U.S.

The discussion here is limited to central cities, for which data are available for commercial and industrial properties. Central cities have experienced a wide range of growth experience in the United States, with about 29 percent suffering decline, 39 percent stagnation, i.e. growth at less than the overall rate of population growth in the U.S., and the remaining 32 percent experiencing faster growth. Central cities also range widely in size, from a minimum of 11,000 to 8 million in the case of New York City.

The first model regresses population growth on job growth (in cities with job growth) and on job decline (in cities with job decline), and shows an asymmetry between cities that grow and decline. For cities that decline, there is population inertia as population adjustments to job decline are much smaller than to job growth. Population is relatively immobile in adversity, preferring to stay put, as housing is difficult to sell and social capital difficult to transfer. As a result of a declining employment share, one would expect decreased earnings and falling wage rates. While this leaves the population worse off, it also lays the seeds for a rejuvenation and more limited job decline than would be the case otherwise.

The second model shows that the reuse of legacy capital indeed contributes to central city growth. It also deals with the differences in the impact between industrial properties and offices. As discussed in Chapters 3 and 4, we would expect a high vacancy rate of industrial properties to impede growth, but the actual absorption and conversion of industrial property to be positively related to growth. The second prediction is confirmed, while the former is not. The model shows that a high vacancy rate of industrial properties has a small but marginally positive significant impact on population growth. This suggests the need for further research. One reason may be that a high industrial vacancy rate is consistent with a small industrial employment share, so that industrial decline will have little impact. Another reason is that abandoned property is no longer counted as vacant, and hence is omitted from the vacancy rate.

A third model shows that agglomeration economies as measured by the size of a central city are positively related to its growth. With the impact of job growth already accounted for, the larger a central city, the higher its growth rate. This suggests that size is rewarded, and that for equal job growth, central cities tend towards increasing size inequality, as larger cities experience higher growth rates than smaller cities. It is difficult to see however, how this result could be sustainable in the long term, given that central cities almost never have room to expand in physical size. Further, it does not necessarily mean that larger cities grow faster than smaller cities, as the population growth rate is more strongly determined by the rate of job growth.

The central theme underlying the five essays is how city assets including legacy capital and agglomeration economies impact urban amenities and productivity and the path of urban growth and decline. My dissertation provides a novel model of the abandonment of legacy capital and shows empirically how property with different conversion costs impacts abandonment and urban revitalization. It explains the reasons for the differences in the path of urban decline and suggests urban policies to mitigate the decline. Urban growth and decline has long been a topic of research, stimulated by the decline of industrial cities starting in the 1960s and the growth of mining boom towns in the 1970s. My research is part of the growing literature dealing with urban growth and decline based on the notion of path dependency – current and future change depends on actions taken in the past. The significance of my research lies in the novelty of its topics and verification method, and its policy implications.

Chapter 2: Disentangling Agglomeration Economies − Agents, Sources, and Spatial Dependence

2.1 Introduction

On the surface, the concept of agglomeration economies is simple enough. As the size of an urban economy increases, its firms become more productive and its consumers enjoy greater amenities. Without agglomeration economies, there could be no trade, and population would distribute itself uniformly over space, except for concentrations in locations with increased resource endowments or higher productivity. However, the mechanisms and causes of agglomeration economies are difficult to model, and without this there are few policy variables other than direct interventions that change the size of cities or redirect migrants. This paper aims to deconstruct the concept in three ways.

First, it disentangles the effect of agglomeration economies on three agents – consumers and firms in two sectors, a traded good sector and a sector producing local goods. Size will affect these sectors differently, and possibly, in opposite direction, and only a model that explicitly accounts for the behavior of all three agents will be able to account for their separate role in generating agglomeration economies. Most studies of agglomeration economies, however, look only at either the productivity of firms or the quality of life for consumers. Yet both of them interact and thus must be considered simultaneously. If the size of an agglomeration enhances consumers' well being, then all else equal, they are willing to work at lower wages, impacting firms' costs. Conversely, if the size of an agglomeration improves a firm's productivity, this raises a worker's wages and impacts her willingness to pay for housing or to incur congestion.

Second, it clarifies the role of population size as a source of economies by introducing a bundle of agglomeration factors that are more directly a source of amenity and productivity gains. These include factors identified in the literature as possible sources of economies, such as the sharing of infrastructure, manufacturing localization, the level of human resources, and the quality and cost of public services. It is in the nature of these factors that they both impact the economy and are affected by it. The results are a more detailed understanding of the sources of agglomeration economies, better estimates of the impact of population size, and the availability of policy variables. Many studies, however, look only at the effects of agglomeration size. This means that there are few policy implications, as agglomeration size itself is not a policy instrument. It is true that many urban policies related to infrastructure and public services depend on city size, but they are not completely determined by it but rather are influenced by factors under a policymaker's control. Moreover, some agglomeration factors have positive effects while others have negative effects, and as a result they offset each other. Hence measuring the net effect of agglomeration size does not capture the underlying effects individually. Yet it is these individual effects that are of interest in making policy decisions.

Third, it identifies spillover effects associated with agglomeration economies. A number of recent estimates show that agglomeration economies have a high rate of spatial decay, and will not have an important effect beyond relatively short neighborhood distances. On the other hand, metropolitan areas all over the world continue to grow, and often extend over distances of 100km or more, making it likely that at least some agglomeration factors affect neighboring spatial units at some distance. For instance, a central city affects its suburban neighbors, people commute and shop across administrative boundaries, and firms are part of demand-supply chains across close-by regions. This paper investigates how spatial units impact their neighbors, and in return are impacted by them, changing the productivity and quality of life across borders. In short, this paper aims to provide a more complete picture of agglomeration effects by disentangling them along three dimensions: impacted agents, impacting factors, and spatial dependence. Specifically, it measures the implicit values that individual consumers and firms in own and neighboring regions place upon agglomeration factors, allowing us to estimate not only the effectiveness of a policy in raising productivity and quality of life but also to separate out gross agglomeration economies and diseconomies, and to identify own and neighborhood effects.

For this purpose, we propose a spatial simultaneous equations model and apply it to data for Ohio counties. An urban economy's equilibrium is the result of interactions between all economic agents, and observables are mostly the results of those interactions. A single equation model in reduced form describing the observables would fail to capture the separate effects of agglomeration factors on individuals and firms and hence there is a need for a simultaneous equations model (SEM) explaining structural economic forces. In addition, investigating the spatial dependence of these effects requires a spatial framework as well. Thus we incorporate the simultaneous framework into a spatial autoregressive (SAR) model with spatial lags and spatial errors to build a simultaneous system of spatially interrelated equations. The model is estimated using the generalized spatial three stage least squares (GS3SLS) suggested by Kelejian and Prucha (2004).

The paper is organized as follows: Section 2.2 motivates the paper and reviews the literature on agglomeration economies. Section 2.3 develops a theoretical model designed to measure separately the effects of agglomeration size and its factors on both consumers and firms in the traded good and housing sectors. Section 2.4 constructs the empirical model designed to measure the spillovers of agglomeration economies as well, and explains the estimation method. Section 2.5 shows the estimation results of the model using empirical data of Ohio's regional economy. Section 2.6 discusses policy implications and the significance of the results. Finally, Section 2.7 suggests possible extensions of the paper.

2.2 Literature Review and Motivation of paper

2.2.1 Literature on Agglomeration Economies

The concept of agglomeration economies has been at the center of regional science research, as it explains why people and firms concentrate to form a city and why cities of different sizes exist. Since the 1970s, a vast amount of work in urban economics has tried to estimate the size of agglomeration economies and diseconomies. Recent years have seen the emergence of a rather different stream of literature in the form of the new economic geography (NEG), initiated by Krugman's (1991b) seminal work. While the former explains agglomeration economies as a location specific characteristic, the latter tries to explain it as a result of interregional interdependence at a larger spatial scale (Brakman & van Marrewijk, 2009; Brakman, Garretsen, & van Marrewijk, 2009; Combes et al., 2005). Despite differences in focus, both streams of the literature have analyzed sources and magnitudes of (dis)economies in terms of gains (or losses) in productivity and quality of life, though empirical estimates with few exceptions emphasize on the production side.

In his excellent survey, Puga (2010) identifies three mechanisms of agglomeration economies bringing productivity gains to firms: a *sharing* of local facilities, intermediate input suppliers, and/or a pool of workers; a better *matching* in goods and labor markets; and a *learning* or knowledge spillover. First, the sharing of indivisible facilities has long been recognized as a major source of economies particularly by the public economics literature (Andrews & Swanson, 1995; Eberts & McMillen, 1999; Morrison & Schwartz, 1996; Munnell, 1990; Munnell, 1992); see Scotchmer (2002) for a review. A large pool of intermediate input suppliers can also reduce transaction costs (Abdel-Rahman & Fujita, 1990; Holmes, 1999; Rosenthal & Strange, 2001), and labor pooling can smooth out idiosyncratic shocks (Combes & Duranton, 2006; 1997; Francis, 2009; 2009; Rosenthal & Strange, 2004). Second, the probability and quality of matching between employees and employers, and suppliers and buyers increases with market size, though more research is needed to find out its exact mechanism (Andersson, Burgess, & Lane, 2007; Coles, 1994; Coles & Smith, 1998; Gan & Li, 2004; Helsley & Strange, 1990). Third, there is a huge amount of studies, both empirical and theoretical, that suggests that larger agglomerations better develop and faster adopt new technologies and practices (Anselin, Varga, & Acs, 2000; Charlot & Duranton, 2004; Duranton & Puga, 2004; Fujita & Ogawa, 1982; Glaeser, 1999; Glaeser & Mare, 2001; Jacobs, 1969; Lim, 2004; Lucas & Esteban Rossi-Hansberg, 2002; McCann & Simonen, 2005; Ota & Fujita, 1993; Paci & Usai, 1999).

For consumers, a larger agglomeration may raise the quality of life both directly and indirectly, as income grows with greater productivity. Larger markets support a greater variety of goods and services that benefit consumers (Brakman, Garretsen, & Marrewijk, 2001; Fujita, Krugman, & Venables, 1999; Krugman, 1991b; Stahl, 1982). Greater competition in larger market benefits consumers in the form of lower prices; see for example recent evidence on the price effects of large low-cost retailers (Fu, 2007). Network economies and infrastructure indivisibilities also favor larger over smaller cities or rural areas; and the public economics literature provides much evidence that a higher quality of public services raises utility, as reflected in higher housing prices or land rent (Burnell & Galster, 1992; Carlsen, Jørn Rattsø, Bjørg Langset, & Lasse Stambøl, 2006; Gabriel, Mattey, & Wascher, 2003; Gyourko & Tracy, 1989; Mozayeni, 1995; Nechyba & Strauss, 1998; Oates, 1969; Oates, 1973; Pollakowski, 1973; Rosen & Fullerton, 1977; Tiebout, 1956).

While the above examples all point to the positive effects of a larger agglomeration, there are of course, also negative effects, such as traffic congestion and pollution (Higano & Shibusawa, 1999; Tabuchi, 1998; Zheng, 2001). Given road capacity, the congestion associated with a greater traffic volume raises firms' transaction costs and decreases individuals' utility. In addition, infrastructure quality comes at a price, and hence, one needs to account for the costs of supplying it. The net effect should be the benefits on the demand side net of the costs on the supply side.

The literature also looks at spatial spillovers of agglomeration economies. In focusing on firms' productivity most studies suggest that spillovers decay rapidly with distance, and are confined to a scale smaller than a city or county. Duranton and Overman (2005) suggest that a majority of U.K. firms are localized in areas of less than 50 km across. Desmet and Fafchamps (2005) maintain that service sectors experience high growth in agglomeration centers but low growth beyond 5 km, and that non-service sectors grow fast at a distance 20 – 70 km from the centers. Van Soest, Gerking, and van Oort's (2006) in a study of South-Holland suggest that the impact of agglomeration economies on employment growth and the birth of establishments is significant at a scale smaller than a city. Hanink (2006) in a study of the New England region argues that external scale effects do not extend to neighboring counties for most sectors except retailing and services, while other researchers argue for an even smaller scale. Rosenthal and Strange (2003) show that the effect of own two-digit SIC industry employment is 10 to 1,000 times larger within one mile than in an area two to five miles away. Fu (2007) also finds that the external effect on wages of human capital depth decays steeply beyond three miles from the work place. But all these studies on spatial spillovers deal only with firms' productivity rather than consumers' amenity. Since the spatial extent of amenity spillovers may differ from that of productivity spillovers, a separate investigation is needed for the former.

2.2.2 Motivation of the Paper

The literature is well aware of the many agglomeration effects on quality of life and productivity. Still empirical studies mostly deal with the latter rather than the former, and very few studies look at both simultaneously. Many researchers in the traditional urban economics investigate production or cost mainly as a function of *city size* (Carlino, 1982; Henderson, 1986; Moomaw, 1981; Moomaw, 1983; Segal, 1976); see Eberts and McMillen (1999) for review. Recent studies in NEG look at other aspects of agglomeration such as labor market pooling, market potential, and specialization. Specifically, Wheaton and Lewis (2002) investigate the effects of labor market agglomeration on firms' productivity in terms of wages; Hanson (2005) looks at market potential effects; and Gibbs and Bernat (1997) investigate the effects of sector specialization on regional wages. But these studies still focus only on the effects on firms' productivity, not quality of life.

In a different context, Roback (1982) provides a useful framework for analyzing the simultaneous effects of regional attributes on individuals' quality of life and firms' productivity. She provides a spatial equilibrium model to capture the two effects and applies it to U.S. cities, though population size is regarded as one of exogenous regional attributes rather than an endogenous variable it should be. As people migrate to a region with good amenities, the size of this region increases, making population size endogenous (Ciccone & Hall, 1996; Henderson, 2003; Koo, 2005). Moreover, some of her empirical results are inconclusive. One would have expected regional attributes to raise land rents if they are valued positively by residents, and to reduce land rents if they are valued negatively. However, no clear sign emerges.

Tabuchi and Yoshida (2000) investigate the consumption and production side of agglomeration effects separately, making use of Roback's (1982) framework, as we do in this study. However, there are at least two limitations. First, their study considers the effects of population size, but does not allow for other agglomeration factors. Second, they use land rent rather than housing price as an endogenous variable. This creates a systematic bias, as residents consume housing service rather than land and thus their utility is affected directly by housing price and not land rent; see Section 2.3 for a detailed discussion. In the U.S. of course, land rent data are typically lacking. Hence, both on theoretical and practical grounds, we turn to housing price data.

Research on agglomeration spillovers so far has focused almost exclusively on firms' productivity rather than consumers' amenities. Hence, research on the rate of decay of spillover effects must be expanded to amenities. Given that an individual's life often extends far beyond administrative boundaries of her city or county, amenity effects may well also extend much beyond these boundaries. Confirming this hypothesis requires a separate investigation of spatial spillovers of amenity effects from agglomeration.

This study investigates the effects of various agglomeration factors including agglomeration size, considering simultaneously the consumption and production side of the regional economy. It also looks at the spillovers of these agglomeration economies and identifies their neighborhood effects for each agent. In doing so, we determine the implicit values of several policy-driven agglomeration factors related to public service levels including road density, traffic flow, and public expenditure level. In extending Roback's model to use housing price and population size as endogenous variables, we improve the model's realism and applicability to available data. In extending Tabuchi and Yoshida's study to incorporate agglomeration factors, we are able to quantify these factors and obtain richer policy implications.

Theoretically, our model follows an urban economics framework rather than NEG. This is appropriate for the problem being addressed as we deal with economies that are small, relative to the rest of the world and hence are price takers. As in urban economics, the size of the city is determined based on a postulated spatial equilibrium and the ability of labor to move freely between regions; see Glaeser and Gottlieb (2009) for a review. Trade relations and transport costs are not explicitly modeled, except that different producers must overcome different transportation costs to access world markets. This is appropriate, as a more explicit modeling of interregional linkage trade is more relevant at a large scale than at a smaller urban economy scale (Brakman and van Marrewijk, 2009; Brakman, Garretsen, and van Marrewijk, 2009). However, our model emphasizes spatial linkages in the form of spillovers from agglomeration factors to neighboring areas. Agglomeration economies and diseconomies are modeled by a shift up or down of total factor productivity as a function of agglomeration characteristics under constant returns to scale. This framework allows us to explain both economies and diseconomies of agglomeration factors, while the NEG framework assumes increasing returns to scale and thus usually neglects diseconomies (Brakman et al., 2009). Hence we mainly follow the urban economics framework,[1] though extend this framework by allowing for spatial spillovers and transportation costs to major trade posts, i.e. airports.

[1] Combes, Duranton, and Overman (2005) also argue that urban economics is more relevant in explaining 'spikes' of economic activities at the smaller scale of a city or region, while NEG is good in explaining

2.3 The Theoretical Modeling: Effects of agglomeration factors

2.3.1 Measurement of Agglomeration Economies

Here we seek to explain how to measure productivity and amenity gains and losses. We base our methodology on a study on the impact of agglomeration factors on equilibrium wages and rents. Puga (2010) summarizes three approaches to measure productive advantages of agglomeration: One may show that economic activities are more agglomerated than would be expected; one may estimate the geographical variations of wages and land rents, as amenities and productive advantages of agglomeration are priced by labor and land markets; and one may investigate directly productivity variations across space at the level of individual firms. We follow the second approach as it captures effects on both productivity and quality of life while the other two focus mainly on productivity advantages.

In line with this approach, Roback (1982) suggests a spatial equilibrium framework that uses geographical variations in wages and rents to study location-specific amenity and productivity effects of regional attributes such as climate, priced in land, housing, and labor markets (Blomquist, Berger, & Hoehn, 1988; Knapp & Graves, 1989; Roback, 1982). Her model tells us that all else being equal, a region's productivity advantages and consumption amenities respectively raise wage rates and land rents. However, when a regional attribute impacts both productivity and quality of life, the relation becomes more complicated. Still, looking at the systematic spatial patterns in wages and rents enables us to disentangle its impacts on production and consumption.

As an example (Puga, 2010; Roback, 1982), consider a worker-consumer and a firm, both consuming a region's land. If the land rent is high, a worker-consumer must be compensated by a higher wages while the firm must reduce wages to keep production costs competitive. In other words, the worker-consumer is indifferent between high wages and high land rents, while the firm is indifferent between low wages and high land rents. An equilibrium bundle of wage and rent is determined by the two parties' interaction in the labor market. But interregional interaction also plays a role in determining the wage and rent. Assuming that workers and firms are mobile, spatial equilibrium requires that a worker's utility and a firm's unit-cost are equal across all regions. Hence, the firm should pay a high wage and a high land rent where productivity is high; and a high quality of life makes individuals willing to accept a high land rent and a low wage. As a result, equilibrium land rent should be high in a region where productivity and amenities are both high, while it is ambiguous whether equilibrium wage is high or low in that region.

These relationships are illustrated in relation to agglomeration attributes in Figure 2.1. Consider a representative worker-consumer and a representative firm. The worker-consumer's indirect utility function $V(w, r; \mathbf{s})$ is an upward sloping curve, where w, r, and $\mathbf{s}$ denote wage, rent, and a vector of agglomeration attributes, respectively, as she is indifferent between high wages and high rents. The firm's unit cost function $C(w, r; \mathbf{s})$ is downward sloping, as it is indifferent between high wages and low rents. When the vector of agglomeration attributes takes a value of $\mathbf{s_1}$, the equilibrium is formed at the intersection EQ1 between the indirect utility function and the unit-cost function. Now suppose that the vector of agglomeration attributes changes from $\mathbf{s_1}$ to $\mathbf{s_2}$. If the change raises the individual's utility level only, then the indirect utility curve $V(w, r; \mathbf{s})$ shifts downwards as she is willing to accept low wages for given rents due to the improved quality of life. Thus the equilibrium moves from EQ1 to EQ3 for a given firm's cost level. Similarly, if the agglomeration factor raises the firm's productivity only, then the unit-cost curve $C(w, r; \mathbf{s})$ shifts upwards as it is willing to accept high wages for given rents due to the increased productivity. Thus the equilibrium moves from EQ1 to EQ2 for a given individual's utility level. If the agglomeration factor change raises both quality of life and productivity, the equilibrium moves from EQ1 to EQ4 and thus the change in rent is positive while the change in regional wages is ambiguous.

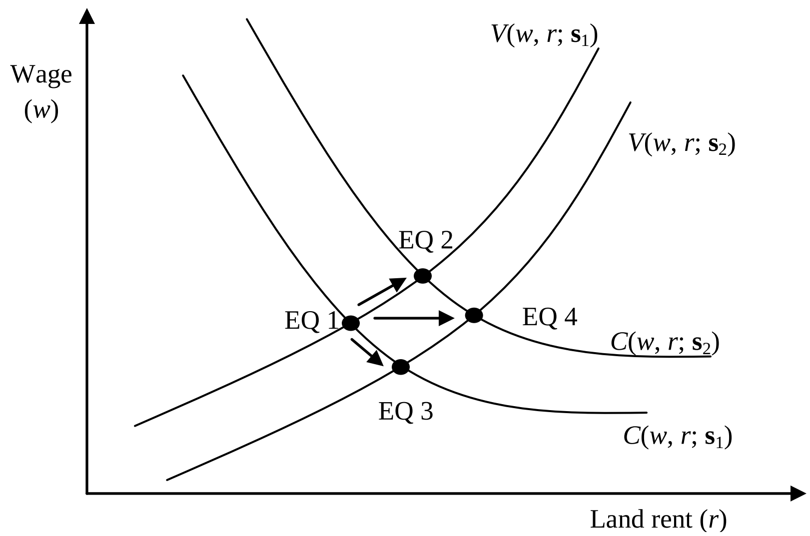

Figure 2.1: Wage-Rent Gradient

To summarize, the above example shows a particular change in attributes using a graphic representation of two equations model for production and consumption. Many changes can be traced in the same way. It shows that land rents and wages must be modeled to capture simultaneously an agglomeration effects on a firm's productivity and a consumer's quality of life. This requires a SEM consisting of two structural equations to describe separately the underlying effects on consumers and firms.

There are two additional complications however, not captured by the above graphical framework. First, there is a need for a third agent, in the form of the housing sector, to model the fact that workers consume housing rather than land (as in the model discussed above). In a two sector representation of the economy, where housing price serves as a proxy for land rent, an agglomeration factor's productivity and amenity gains should both lead to a rise in housing price. Instead, with a proper modeling of the housing sector, the effect on housing prices is ambiguous, because productivity gains in the housing sector lowers the housing price while increased land rents raise it. Hence in our model, labor is an input into both traded good and housing sectors, land is an input largely into the housing sector, and individual worker-consumers consume the traded good and housing with their income. While individual consumers determine their place of residence, traded good and housing firms determine wage rate, land rent, and housing price. It takes the housing sector to capture all of this correctly.

Second, one must take account of the endogeneity of agglomeration factors. Agglomeration factors such as infrastructure and public service quality impact the urban economy and in turn are influenced by it. In this they differ from other regional attributes such as climate or location, where such feedbacks do not exist. As a result agglomeration factors may be correlated with disturbance terms, leading us to introduce instrument variables (IVs), as discussed in Section 2.4 dealing with empirical modeling. It is possible of course to model the feedback for each factor through additional structural equations, though this would vastly complicate the model and make additional data demands not dealt with here.

2.3.2 Assumptions and Model

For the spatial setting, we assume that there are many regions that have different agglomeration factors such as variety, specialization, and provision of infrastructure and public services. Each region is defined by its labor market so that workers do not commute beyond their region on a daily basis, once they determine their location of residence. In the long term, however, capital and labor can move freely across regions, and hence a long-run spatial equilibrium is formed equalizing individuals' utility and firms' unit-cost across regions. The model in the paper deals with this long-run equilibrium.[2]

We follow Roback's (1982) extended model to make the following assumptions: On the production side, each region has two sectors, one producing a traded-composite good, the other non-traded housing. Each sector's production function is described by a representative firm that produces its output under constant returns to scale (CRS) at the firm level but potentially increasing returns to scale (IRS) at the industry level. This is a typical assumption in the urban economics literature dealing with agglomeration economies or diseconomies, while NEG assumes IRS production at the firm level (Brakman et al., 2009). We follow the traditional approach of urban economics, as explained in Section 2.2. The traded good sector produces a composite good with labor, capital and land as inputs; the housing sector produces housing with the same inputs. Regarding taxation, we assume that representative firms pay all their taxes in the form of a sales tax that varies across regions, and thus the regional price of a good rises with the regional tax rate. On the consumption side, a single worker-consumer represents all individuals' preferences in each region. This worker is employed by one of the two representative firms, and consumes the traded-composite good and housing in competitive markets to maximize her utility. The individual's income consists of her wage and other earnings from factor endowments such as dividends, interest, and rent. Production factors across all regions are equally owned by all worker-consumers of all regions. Particularly, each person has the same portfolio of land ownership across all the regions regardless of her location of residence. Hence, of her income components, only wages vary with her choice of location. Assuming no inter-sectoral wage

[2] We think of the long-term as extending beyond 20 years, as infrastructure works often have a design and implementation horizon at least that long, and the effect of localization economies may take even longer to be fully realized.

difference or free mobility of labor across sectors within a region, one can say that a fraction of a representative worker-consumer's income comes from the traded good sector and the rest from the housing sector. Regarding the taxation, we assume that the representative worker-consumer pays all taxes in the form of a lump-sum tax that varies across regions and thus her disposable income decreases by that amount.

The individual worker-consumer's utility maximizing program gives us an indirect utility function for the representative individual in region *i* as follows:

$$V(hpric_i, (inc_i - ctax_i); \mathbf{z}_i) = k \tag{2.1}$$

where $hpric_i$, inc_i, $ctax_i$, and $\mathbf{z}_i$ are housing price, income, tax payment, and a vector of regional attributes including agglomeration factors that possibly affect the individual's utility in region *i*. The utility is equalized across regions and thus it has a constant value, *k*, regardless of regions.

Since the two goods are produced under CRS, the two representative firms' cost minimizing programs give us two unit-cost functions for the two sectors in region *i* as follows:

$$C(p_K, indr_i, wag_i; \mathbf{z}_i)(1 + trtxrt_i) = 1 \tag{2.2}$$

$$G(p_K, resr_i, wag_i; \mathbf{z}_i)(1 + hstxrt_i) = hpric_i \tag{2.3}$$

where *C* and *G* denotes the unit-cost functions for the traded composite good and housing sectors, respectively; p_K, $indr_i$, wag_i, and $resr_i$ are capital rent, industrial land rent, wage, and residential land rent; and $trtxrt_i$ and $hstxrt_i$ are tax rates for the traded good and housing sectors, respectively in region *i*. Note that $\mathbf{z}_i$ the vector of regional attributes appears again as it possibly affects the firms' productivities. As capital is mobile, the capital rent is constant across regions. The unit-cost of the traded good is also equalized across regions since the good moves freely across regions. So the good can be regarded as numéraire, and its price is normalized as unity. The unit-cost of housing is not traded and hence differs across regions. The housing price, $hpric_i$, therefore is variable. Note that the vector $\mathbf{z}_i$ has as its elements population size pop_i, a sub-vector of other agglomeration factors $\mathbf{s}_i$, and another sub-vector of all other regional attributes $\mathbf{q}_i$. In other words, the vector $\mathbf{z}_i$ is written as $(pop_i, \mathbf{s}_i, \mathbf{q}_i)$.

As to functional forms, we use the Cobb-Douglas function for both the utility and production functions and introduce a shift factor that changes utility or productivity levels depending on regional attributes for a given bundle of consumption. First, the representative worker-consumer's utility is determined by her consumption of the traded good and housing, and it also is shifted by regional attributes including agglomeration factors. Assuming the separability of population size from other regional attributes in the shift factor, her utility function may be written as

$$U = A(\mathbf{s}, \mathbf{q}) pop^{a_1} g^{\theta} h^{1-\theta}$$

where $A(\cdot)$ represents a utility shift by regional attributes ($\mathbf{s}$, $\mathbf{q}$) and thus $A(\mathbf{s}, \mathbf{q}) pop^{a_1}$ is the utility shift by all regional attributes; g and h are quantities of the traded good and housing; and parameters a_1 and θ represent the elasticity of utility with respect to population size and the share of expenditure on the traded good out of total expenditure, respectively. Next, for the production functions of the two sectors, we assume that the representative firm's total factor productivity (TFP) is determined by regional attributes. Assuming the separability of population size, the production functions may be written as

$$g = F(\mathbf{s}, \mathbf{q}) pop^{b_1} L_g^{\alpha_1} N_g^{\beta_1} K_g^{\gamma_1} \tag{2.4}$$

$$h = H(\mathbf{s}, \mathbf{q}) pop^{c_1} L_h^{\alpha_2} N_h^{\beta_2} K_h^{\gamma_2} \tag{2.5}$$

where $F(\cdot)$ and $H(\cdot)$ represent productivity shifts due to regional attributes ($\mathbf{s}$, $\mathbf{q}$); N, K, and L indexed by output denote labor, capital and land; and parameters b_1 and c_1 represent the output elasticities with respect to population, while α's, β's, and γ's the output elasticities with respect to the three corresponding inputs as usual. Note that we have assumed Hicks-neutrality in technical changes due to regional attributes. In other words, regional attributes affect the productivities of all the inputs equally and shift outputs neutrally across inputs, while they do not change returns to scale.[3]

The optimization programs of the three agents give us the indirect utility function and the two unit-cost functions as follows:

$$V = A(\mathbf{s},\mathbf{q})pop^{a_1}\,\theta^{\theta}\left(\frac{1-\theta}{hpric}\right)^{1-\theta}(inc - ctax) = k \tag{2.6}$$

$$C = \frac{1}{F(\mathbf{s},\mathbf{q})pop^{b_1}}\left(\frac{indr}{\alpha_1}\right)^{\alpha_1}\left(\frac{wag}{\beta_1}\right)^{\beta_1}\left(\frac{p_K}{\gamma_1}\right)^{\gamma_1} = \frac{1}{1+trtxrt} \tag{2.7}$$

$$G = \frac{1}{H(\mathbf{s},\mathbf{q})pop^{c_1}}\left(\frac{resr}{\alpha_2}\right)^{\alpha_2}\left(\frac{wag}{\beta_2}\right)^{\beta_2}\left(\frac{p_K}{\gamma_2}\right)^{\gamma_2} = \frac{hpric}{1+hstxrt} \tag{2.8}$$

where the second equalities in the above equations come from Equations (2.1) − (2.3). Note that the index *i* for each region is dropped for simplicity as it is obvious that each equation represents each economic agent's behavior in a specific region. The system of equations is indeterminate because it has only three equations but six unknown variables, *pop*, *inc*, *indr*, *wag*, *resr*, and *hpric*. We deal with this by imposing additional assumptions on people's income, land input in the traded good sector, and residential land rent. Specifically, the wage variable in (2.8) is expressed as a function of income as wage is the only income component varying across regions. Using the income share of wages, the wage variable is expressed as an exponential function of the income variable; see Appendix A for details. Second, the share of land input in the traded good sector is negligible and thus factor returns take the form of wages and capital rent only. Given that capital

[3] Productivity changes may also be measured by changes in returns-to-scale $\delta = \alpha + \beta + \gamma$. The current framework assumes constant returns to scale technology in all regions and thus this measure stays constant across regions. For the difference between the two approaches, see Eberts and McMillen (1999).

rent is constant, a productivity increase leads only to an increase in wages and hence all the productivity gains return to regional income. In other words, the factor price index consisting of factor prices, $(indr/\alpha_1)^{\alpha_1}(wag/\beta_1)^{\beta_1}(p_K/\gamma_1)^{\gamma_1}$ in (2.7) represents regional income coming from the traded good sector and hence can be expressed as a function of regional income. Third, residential land rent is proxied by other variables and parameters, specifically, population, housing price, and land area; see Appendix A for details. With these three assumptions, the system of simultaneous equations is reduced to a determinate system with three unknowns, *pop*, *inc*, and *hpric*. The three equations can be expressed as explicit functions (2.9) − (2.11); see Appendix A for a derivation.

$$\log(pop) \approx a_0 - \frac{1}{a_1}\log(inc) + \frac{1-\theta}{a_1}\log(hpric) + \frac{1}{a_1}\cdot\frac{ctax}{inc} - \frac{1}{a_1}\log\big(A(\mathbf{s},\mathbf{q})\big) \tag{2.9}$$

$$\log(inc) \approx b_0 + b_1\phi\log(pop) - \phi trtxrt + \phi\log\big(F(\mathbf{s},\mathbf{q})\big) \tag{2.10}$$

$$\log(hpric) \approx c_0 + \frac{\beta_2}{(1-\alpha_2)\varpi}\log(inc) + \frac{\alpha_2 - c_1}{1-\alpha_2}\log(pop) - \frac{\alpha_2}{1-\alpha_2}\log(area) + \frac{hstxrt}{1-\alpha_2} - \frac{1}{1-\alpha_2}\log\big(H(\mathbf{s},\mathbf{q})\big) \tag{2.11}$$

where *area* is the area of the region; a_0, b_0 and c_0 are constant parameters; ϕ and ϖ are the income share of the traded good sector and the income share of wages, respectively. One may ignore ϕ as most of a region's income comes in the form of factor prices from the non-housing traded good sector[4] and as it is difficult to extract the per capita income of the traded good sector

[4] According the REIS data, only 4.3 percent of total income in Ohio comes from the construction sector and hence the income share taken by the housing sector may be assumed to be too tiny to influence the total income.

alone. Note that the two constants p_k and k are dropped from the system of equations since they can be embedded in the functional forms along with other constants.

In a nutshell, the model consists of three equations that specify the indirect utility function for the representative consumer (2.9), and the two unit-cost functions of the two sectors (2.10) and (2.11). While (2.9) represents individuals' consumption behavior across regions, (2.10) and (2.11) show firms' behavior in the two sectors. (2.9) suggests that human settlements are determined by income, housing price, and other regional attributes including agglomeration factors. (2.10) tells us that the income coming from the traded good sector is determined by the productivity of the sector, as theoretically and empirically validated by the literature (Hall & Jones, 1999; Solow, 1956). The model suggests that the TFP in turn depends on population size and other regional attributes. (2.11) tells us that the housing price is a function of the income, population density, and productivity, and the productivity in turn depends on regional attributes. Equilibrium population, income, and housing price are obtained through interactions among the three economic agents in the labor and housing markets not only within a region but also across regions because of labor mobility. The system of equations has population size, income, and housing price as simultaneously determined endogenous variables, and regional attributes including agglomeration factors as exogenous variables in the mathematical sense.

2.3.3 Imputation of a Regional Attribute's Value

Given the indirect utility function and the unit-cost functions in the two sectors, the value of a regional attribute including agglomeration factor is computed as its implicit price for the representative individual and as its effect of cost savings for the two sectors.

First, the effect on individuals' utility of an attribute is measured in terms of its implicit price, that is, the income that is willing to be given up to get that factor to maintain the same level of quality of life (Roback, 1982). Formally, the implicit price $p_{z_j}^*$ of an attribute z_j is computed as:

$$p_{z_j}^* = \frac{V_{z_j}}{V_{inc}} \tag{2.12}$$

where V_{z_j} and V_{inc} denote the partial derivatives of the indirect utility function with respect to the attribute z_j and income, respectively. Substituting (2.6) for the indirect utility function in (2.12) yields the implicit price of the attribute z_j and population size as

$$p_{z_j}^* = \frac{\partial \log(A(\mathbf{s}, \mathbf{q}))}{\partial \log(z_j)} \cdot \frac{inc}{z_j} \tag{2.13}$$

$$p_{pop}^* = a_1 \cdot \frac{inc}{pop} \tag{2.14}$$

Equivalently, (2.13) can be also expressed using the explicit form of indirect utility function in (2.9) as follows:

$$p_{z_j}^* = \frac{\partial \log(pop)/\partial \log(z_j)}{\partial \log(pop)/\partial \log(inc)} \cdot \frac{inc}{z_j} \tag{2.15}$$

Since (2.9) suggests that $a_1 = -1/[\partial \log(pop)/\partial \log(inc)]$, the implicit price of population size in (2.14) is written as

$$p_{pop}^* = -\frac{inc/pop}{\partial \log(pop)/\partial \log(inc)} \tag{2.16}$$

If the implicit price is positive, then the factor is an amenity to individuals. Otherwise, it is a disamenity.

The effect on productivity is represented by cost savings or increases incurred by firms to produce the same quantity of goods. Formally, the cost change caused by an regional attribute z_j can be represented in terms of the elasticity of cost as follows:

$$e_{Cz_j} = \frac{\partial \log(C)}{\partial \log(z_j)} \tag{2.17}$$

$$e_{Gz_j} = \frac{\partial \log(G)}{\partial \log(z_j)} \tag{2.18}$$

where C and G are unit-costs for the two sectors, and e_{Cz_j} and e_{Gz_j} denote the elasticities of cost with respect to the attribute z_j, for the two sectors, respectively. Substituting (2.7) and (2.8) for the unit cost functions in (2.17) and (2.18) yields the elasticities of cost as follows:

$$e_{Cz_j} = \frac{\partial \log\left(F(\mathbf{s}, \mathbf{q})\right)}{\partial \log\left(z_j\right)}$$

$$e_{Gz_j} = \frac{\partial \log\left(H(\mathbf{s}, \mathbf{q})\right)}{\partial \log\left(z_j\right)}$$

Equivalently, they can be also expressed using the explicit functions of production costs for the two sectors in (2.10) and (2.11). As explained earlier, cost savings in the traded good sector lead to regional income increases with the elasticity of the income share of that sector, i.e. $\partial \log(inc)/\partial \log(C) = -\phi$. Cost savings in the housing sector obviously lead to housing price decreases with the elasticity of one in competitive housing markets, i.e. $\partial \log(hpric)/\partial \log(G) = 1$. Using these relationships, the cost elasticities in (2.17) and (2.18) can be written as

$$e_{Cz_j} = -\frac{1}{\phi} \cdot \frac{\partial \log(inc)}{\partial \log(z_j)} \tag{2.19}$$

$$e_{Gz_j} = \frac{\partial \log(hpric)}{\partial \log(z_j)} \tag{2.20}$$

If the cost elasticity of a factor is negative the factor causes a productivity gain, and otherwise a productivity loss.

Sometimes, policy makers are more interested in the effect on residents' income of a sector cost change than the cost change itself. So it is relevant to translate the above cost elasticity to a dollar income change. For the traded good sector, all the cost savings due to productivity increase are captured by worker-consumers through wage increases, since the price of the traded good is given. Using the relation in (2.19), the cost elasticity with respect to a factor is directly translated into wage-income change per sector worker, or the latter can be computed directly from the income equation (2.10). Formally they are computed as

$$p_{z_j}^{C} = \frac{1}{\phi} \cdot \frac{\partial inc}{\partial z_j} \tag{2.21}$$

For the housing sector, however, the effect is not straightforward as productivity changes affect both the housing price directly and factor returns. We introduce the notion of 'willingness-to-pay-wages' to measure the valuation of an agglomeration factor by a representative housing firm. This is the hypothetical wage-income increase that the firm is willing to pay its workers to compensate for a productivity increase while holding production cost and hence housing price constant. This can be computed as the implicit price of an attribute to a consumer. That is, take the ratio of the partial derivatives of the cost function with respect to the attribute and with respect to wage-income. Equivalently, it can be expressed using the explicit function of housing production cost in (2.11) as follows:

$$p_{z_j}^{G} = \frac{G_{z_j}}{G_{inc}} = \frac{\partial hpric/\partial z_j}{\partial hpric/\partial inc} \tag{2.22}$$

where $p_{z_j}^{C}$ and $p_{z_j}^{G}$ denote the effects on income of an attribute z_j for the traded good and housing sectors, respectively. This represents the hypothetical increase in the housing sector's wage-income. To derive the per capita income increase for the whole population, one multiplies the result by the income share of the housing sector, $1-\phi$.

2.4 The empirical Modeling

2.4.1 Spatial Econometric Model

The empirical model takes the form of the simultaneous equations model SEM (2.9) – (2.11) to represent the behavior of worker-consumers and firms in the traded good and housing sectors. This allows us to separate the effects on the three agents of various agglomeration factors but does not capture the spatial dependence of agglomeration economies. This is particularly problematic in geographically contiguous regions, as the arbitrariness of geographical unit of analysis and spatial processes lead to spatial autocorrelation (SAC) problems. To deal with this, we add a spatial autoregressive (SAR) model with spatial lags and disturbance terms to the three structural equations (2.9) – (2.11) to account for spatial spillovers from agglomeration attributes.

Each equation includes one spatial lag of the dependent variable to capture its spatial spillovers. The auto-regressive spatial lag terms summarize the spillovers of utility and productivities in the two sectors. This is sufficient to measure the order of magnitude of overall spillover effects. The limited number of observations makes it impossible to include the cross-regressive spatial lags and the spatial lags of individual explanatory variables in the model.[5]

[5] There are a number of ways to model neighborhood effects, though most will not be feasible, given limited degrees of freedom. In our case there are several assumptions, all of them shared with LeSage and Pace (2008; 2009), though in their case some of the assumptions were the result of having a single equation model. First, all agglomeration factors have neighborhood effects. Second, the strength of the neighborhood effect, relative to own effect is invariant among agglomeration factors. This is modeled by not permitting a spatial lag of the explanatory variables, but only a spatial lag of the dependent variables, *pop*, *inc*, and *hpric*. Third, the strength of the neighborhood effect, relative to the previous effect is

Spatial errors are introduced to reflect potential spatial dependence in the disturbance process as well. As a result, the model is written as

$$\log(pop_i) = \lambda_1 \overline{\log(pop_i)} + \delta_{10} + \delta_{11} \log(inc_i) + \delta_{12} \log(hpric_i) + \delta_{13} prtxshr_i + \mathbf{s}_i \boldsymbol{\eta}_1 + \mathbf{q}_i \boldsymbol{\zeta}_1 + \varepsilon_{1,i} \tag{2.23}$$

$$\varepsilon_{1,i} = \rho_1 \bar{\varepsilon}_{1,i} + u_{1,i} \text{ with } u_{1,i} \sim iid\ N(0, \sigma_1^2)$$

$$\log(inc_i) = \lambda_2 \overline{\log(inc_i)} + \delta_{20} + \delta_{21} \log(pop_i) + \delta_{22} indtxr_i + \mathbf{s}_i \boldsymbol{\eta}_2 + \mathbf{q}_i \boldsymbol{\zeta}_2 + \varepsilon_{2,i} \tag{2.24}$$

$$\varepsilon_{2,i} = \rho_2 \bar{\varepsilon}_{2,i} + u_{2,i} \text{ with } u_{2,i} \sim iid\ N(0, \sigma_2^2)$$

$$\log(hpric_i) = \lambda_3 \overline{\log(hpric_i)} + \delta_{30} + \delta_{31} \log(inc_i) + \delta_{32} \log(pop_i) + \delta_{33} \log(area_i) + \delta_{34} indtxr_i + \mathbf{s}_i \boldsymbol{\eta}_3 + \mathbf{q}_i \boldsymbol{\zeta}_3 + \varepsilon_{3,i} \tag{2.25}$$

$$\varepsilon_{3,i} = \rho_3 \bar{\varepsilon}_{3,i} + u_{3,i} \text{ with } u_{3,i} \sim iid\ N(0, \sigma_3^2)$$

where $\overline{\log(pop_i)}$, $\overline{\log(inc_i)}$, and $\overline{\log(hpric_i)}$ are the spatial lags of the three dependent variables; $prtxshr_i$ is the share of property tax in income, which is a proxy for the income share of all local taxes in (2.9); $indtxr_i$ is industrial and commercial property tax rate, which is a proxy for the rates of all local taxes of the two sectors in (2.10) and (2.11); δ's are scalar regression, and $\boldsymbol{\eta}$'s and $\boldsymbol{\zeta}$'s are vector parameters with elements of possible zeros; λ's and ρ's are autoregressive parameters for the spatial lags and the spatial disturbances, respectively; ε's are the disturbance terms; and $\bar{\varepsilon}$'s are the spatial lags of the three disturbance terms. The spatial lag of a variable is defined as

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constant with increasing order of neighborhood. There are not cross-regressive effects. While these assumptions impose some limitations in the flexibility of the autoregressive structure, they in fact capture important neighborhood effects so far not modeled in the agglomeration economies literature.

the mean of the variable over the neighboring observations based on the rook's definition of contiguity as usual.[6] This can be expressed with a spatial weight matrix $\mathbf{W}$ that is constructed from a binary $n \times n$ matrix identifying neighbors, standardized by row to sum to unity, where the number of observations is n. Then the spatial lag of a variable y for i^{th} observation is formally defined as $\bar{y}_i = \mathbf{W}_{\boldsymbol{i}}\mathbf{y}$, where $\mathbf{W}_{\boldsymbol{i}}$ is the i^{th} row of the matrix and $\mathbf{y}$ is the vector of the variable for all observations.

The presence of spatial lag terms complicates the interpretation of model coefficients. LeSage and Pace (2008; 2009) point out the difference in the interpretation of the coefficients in models with and without spatial lag term. In the absence of a lag term, there are neither neighborhood effects nor feedbacks from neighbors back to the original spatial unit. They argue that for spatial regression models neighborhood and feedback effects invalidate the conventional interpretation of a regression model. In the autoregressive model, the coefficient of an explanatory variable is no longer the complete partial effect of that variable on the dependent variable – as the complete effect would account for feedback effects. In order to capture the neighborhood and feedback effects appropriately, they suggest estimating the average direct effect (ADE) and average indirect/neighborhood effect (ANE). For the details of ADE and ANE, see Appendix B.

In addition we have derived a measure for the effect on nearest neighbors, i.e. the average first order neighborhood effect (A1NE). This is the effect that a change in one observation unit has on its nearest neighbors on average. It is of interest when thinking about the relationship

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[6] The spatial weight matrix based on the rook's definition of contiguity is commonly used to represent geographical connectivity in the spatial statistics literature (Griffith, 2000; Patuelli, Griffith, Tiefelsdorf, & Nijkamp, 2009; Tiefelsdorf & Griffith, 2007).

between central and suburban areas in metropolitan areas, or the relationship between an urban area and its rural neighbors. While ANE captures the total neighborhood effects, i.e. the effect on all neighbors in a region, including feedback effects throughout the region, A1NE captures only the average effect on first order neighbors as defined by the weight matrix.

For notational simplicity of exposition, suppose another simple data generating process as follows:

$$\mathbf{y} = \lambda\mathbf{W}\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\iota}_n\alpha + \boldsymbol{\varepsilon} \tag{2.26}$$

where $\mathbf{y}$ is a n×1 vector of a dependent variable; $\mathbf{W}$ is a n×n weight matrix; $\mathbf{X}$ is a n×p matrix of regressors except the constant term; $\boldsymbol{\iota}_n$ is a n×1 vector of ones; λ is a scalar spatial parameter; $\boldsymbol{\beta}$ is a p×1 vector of parameters; α is a scalar parameter; and $\boldsymbol{\varepsilon}$ is a n×1 vector of *iid* normal disturbances. LeSage and Pace (2008; 2009) define ADE as the average of own effects on the dependent variable of a change of an explanatory variable in an observation unit. For the model in (2.26), the ADE for the r^{th} explanatory variable is computed as

$$ADE_r = \beta_r \frac{1}{n} tr[(\mathbf{I_n} - \lambda\mathbf{W})^{-1}] \tag{2.27}$$

where $tr(\cdot)$ is the trace operator and β_r is the r^{th} element of the parameter vector $\boldsymbol{\beta}$; see Appendix B for the derivation of (2.27). Note that the ADE is the regression coefficient β_r multiplied by the factor $tr[(\mathbf{I_n} - \lambda\mathbf{W})^{-1}]/n$. We call this factor the average direct effect factor (ADEF). We define A1NE as the average of the weighted average effects on the first order neighbors' dependent variable of a change in an observation unit's explanatory variable. Formally, the A1NE for the r^{th} explanatory variable is computed as

$$A1NE_r = \beta_r \frac{1}{n} tr[\mathbf{W}(\mathbf{I_n} - \lambda\mathbf{W})^{-1}] \tag{2.28}$$

where the matrix $\mathbf{W}$ defines the first order neighbors and their weights; see Appendix B for the derivation of (2.28). Note that the A1NE is the regression coefficient β_r multiplied by the factor

$tr[\mathbf{W}(\mathbf{I_n} - \lambda\mathbf{W})^{-1}]/n$, which we call the average total effect factor (A1NEF). One can show that this factor is increasing in the spatial parameter $\lambda > 0$, which is reasonable as a high value of λ implies high spillovers. The ratio of A1NEF to ADEF, which we call the average first order neighborhood effect to direct effect ratio (A1NDR), gives us the relative strength of the first order neighborhood effect to the direct effect. Formally, it is defined as

$$A1NDR = \frac{tr[\mathbf{W}(\mathbf{I_n} - \lambda\mathbf{W})^{-1}]}{tr[(\mathbf{I_n} - \lambda\mathbf{W})^{-1}]} \tag{2.29}$$

Note that this ratio depends on the spatial autoregressive parameter of the model as well as the exogenous weight matrix, i.e. geographical configuration of observations.

We apply this interpretation of spatial autoregressive models to the valuation of the effects of agglomeration factors. Since spatial lags in the model bring about the neighborhood and feedback effects, this should be taken into account while computing the values of an agglomeration factor for both worker-consumers and firms. The valuation methods set forth in Section 2.3 apply in the same way, but the ADE and A1NE of an agglomeration factor should be substituted for the partial derivative of a dependent variable with respect to that factor for the own effects and the first order neighborhood effects, respectively. When a value is translated to own income equivalent, the reference should be the ADE of income. See Appendix B for the computational details of derivation of these values for consumers and firms.

Note that the model specification and interpretation methods described above lead to a peculiar result for the neighborhood effect of an agglomeration factor. The strength of the neighborhood effect, relative to the own effect is invariant among agglomeration factors. The ratio of the two effects always equals A1NDR, which varies only with agents, i.e. equations. This is caused by the fact that the model does not permit spatial lags of the explanatory variables, but only a spatial lag of the dependent variable in each equation. The overall spillovers are captured by only one spatial parameter λ, and it represents the overall tendency of spatial processes for the agent represented by each equation. Another factor impacting the neighborhood effect is the geographical configuration of observations as summarized by the weight matrix. As A1NDR is a function of the spatial parameter λ and geographical configuration, it summarizes the overall neighborhood effect for each agent.

2.4.2 Data

The model is applied to 88 Ohio counties in 2000, with each county representing a region and spatial unit of observations. The rationale is that 73 percent of Ohio employers work in the counties of residence according to the 2000 census and thus the county can be roughly defined as the relevant labor market. The county is often used as a unit for measuring regional amenities as well (Blomquist et al., 1988; Carlino & Mills, 1987; Hoehn, Berger, & Blomquist, 1987; Rupasingha & Goetz, 2004). Data availability is also a big advantage in selecting the county as spatial unit. The remaining error coming from the arbitrariness of the spatial unit is dealt with by taking into account spatial dependence, discussed in the modeling section.

Variables	Units	Definitions	Data Sources
pop	persons	Total population in the county	2000 Census of population and housing
inc	$/person	Per capita income (in 2000 dollar)	REIS (CA05)
hpric	$	Median housing value (in 2000 dollar)	2000 Census of population and housing
prtxshr	percent	Property tax divided by income	Ohio Department of Taxation, Table PD-23 REIS (CA05)
restxr	mills	Residential & agriculture real property tax millage rate	Ohio department of taxation, Table PR-6
indtxr	mills	Commercial, industrial, mineral real property tax mileage rate	Ohio department of taxation, Table PR-6
pcexp	$/person	County government's expenditure per capita for operating costs in 2001	2002 Census of Governments
rdnt	mi/sq-mi	Total roads length divided by total land area	Ohio Department of Transportation, RI339
water	percent	Share of public supply in domestic water consumption	Estimated Use of Water in the U.S. (USGS)
educ	percent	Share of population with associate's degree or higher	2000 Census of Population and Housing
12*gps*	percent	Average percentage of students who have met minimum State of Ohio scores in reading, writing, math, science and citizenship.	Ohio Department of Education, Proficiency Test Data
szret	emp./est.	Employees per establishment in construction SIC code 33	REIS (CA25), County Business Patterns
pctrf	1000 veh.mi/person	Per capita daily vehicle mile traveled	Ohio Department of Transportation, DVMT reports
lqman		Manufacturing employment share / Total employment share in Ohio	REIS (CA25)
age	yr	Median age of population	2000 Census of population and housing
agesq	yr^2	*age* squared	2000 Census of population and housing
unemp	percent	Annual average unemployment rate	Local Area Unemployment Statistics (LAUS) Program
hyear	yr	Median housing age as of 2000	2000 Census of population and housing
hroom	room/unit	Median number of rooms	2000 Census of population and housing
area	sq. mi.	Land area of the county	2000 Census of population and housing
snow	inch	Annual average snow fall between 1971 and 2000	Midwestern Regional Climate Center (MRCC)

Continued

Table 2.1: Definitions of Variables and Data Sources

Table 2.1 Continued

jantemp	°F	Mean temperature in January between 1971 and 2000	Midwestern Regional Climate Center (MRCC)
Great Lakes	1 or 0	1 if a county is adjacent to the Great Lakes	Author
distair	mile	Distance from the county centroid to the nearest international airport	TIGER/Line® 2000, Google Maps
crime	1/100,000	Average number of violent crimes per 100,000 population reported by FBI over the years of 1999, 2000, and 2002	County and City Data Books(1999 Data), Ohio Office of Criminal Justice Services (2000 and 2002 data)
lqcns		Construction employment share / Total employment share in Ohio	REIS (CA25)
lqret		Retail(SIC 52-59) employment share/Total employment share in Ohio	REIS (CA25)
vacn	percent	Vacancy rate of housing	2000 Census of population and housing
nofreez	day	Number of days when the minimum temperature exceeds 32°F	Midwestern Regional Climate Center (MRCC)

As shown in Table 2.1, data that are published or open to the public are being used from the following sources: Data on wage, income, and employment come from the Regional Economic Information System (REIS) of Bureau of Economic Analysis (BEA). Data on population and median housing value are obtained from 2000 Census of Population and Housing. Data on road density and traffic volumes are provided by Ohio Department of Transportation (ODOT). Taxation data are obtained from Ohio Department of Taxation website, and other regional attributes data come from the Ohio Labor Market Information website (unemployment rate), and Midwestern Regional Climate Center (snow data). The spatial data for county boundaries come from TIGER/Line® 2000, and the coordinates of international airports are obtained from Google Maps. For details of the definition of variables and data sources, see Table 2.1. The descriptive statistics for the variables are reported in Appendix F.

2.4.3 Variables for Agglomeration Factors

Here we identify agglomeration factors and define variables to measure them. Agglomeration factors are chosen to reflect three sources. First, where possible they are designed to reflect the mechanisms or causes by which agglomeration economies and diseconomies are transmitted. Second, they are designed to reflect the effect of the agent missing from the structural equations – government. Third, there are other variables such as the level of human capital, which both impact and are impacted by the size of the agglomeration. In addition, there are other regional attributes, such as climate and geographic variables, which impact productivity and quality of life, but which are exogenous and not correlated to the error term. These are discussed only in the empirical results.

2.4.3.1 Causes of Agglomeration

Consider first the causes of agglomeration. We follow the sources enumerated by Puga (2010) but add population size as a catch-all residual factor that serves as a proxy for congestion as well as better matching, learning and labor pool sharing associated with agglomeration size, for which better measures did not exist. We also treat economies resulting from increased competition (survival of the fittest) as another form of agglomeration economies, as at the aggregate level it is indistinguishable from other economies that raise firm's productivity or reduce consumer's cost. Hence, the causes of agglomeration economies recognized in the model are:

Specialization in Manufacturing: One of the ways agglomeration economies are transmitted is through greater specialization. To measure this element of agglomeration economies, we include a specialization index of location quotient for manufacturing, *lqman*, calculated at the 2-digit SIC code level. While it does not capture variety outside manufacturing or at a higher digit level, it does provide an estimate of the variety of manufacturing and degree of specialization that exists at the county level.

Facility Sharing: Sharing of indivisible facilities has long been recognized as a major source of economies. The problem of course is to find indicators that are substantial enough to have a measurable effect on the economy. The indicators chosen are road density *rdnt*, and the public supply share of domestic water consumption, *water*. The two are public and club goods respectively, and hence, represent a broad range of non-rivalrous goods. Other infrastructure costs are less suitable to serving as a proxy for land development costs, as water and sewer are usually managed by the same authority, telephone and electricity are ubiquitous and hence have no regional variation, and remaining physical infrastructure is too diffuse to be easily measurable. Both proxies are expected to impact productivity in the housing sector rather than the traded good sector, where development costs as small. Subdivision regulations require housing developers to provide infrastructure, and the indicators are suggestive of the ability to socialize development costs that otherwise must be borne by the developer and individual consumer.

Variety: The taste for variety is the dominant source of agglomeration economies modeled in the NEG. Variety is positively associated with density and thickness of market, and as a result, reduced travel distance and lower per capita vehicle traffic flow (*pctrf*). We use per capita traffic flow as an indicator of variety. The greater the density of opportunities, the lower will be per capita vehicle miles traveled. Of course, per capita traffic flow decreases not only because less travel is required to reach a given level of opportunities, it also decreases because a rising density generates greater congestion for given road investments – and hence shifts some of private vehicle travel to public transport. The factor captures both of these effects.

Advantages from Competition: Larger markets increase competition, and this may generate productivity gains associated with the survival of the fittest. The degree of competition is often associated with the size of firms. So we use retail size, as measured by employment per retail establishment, *szret*, as an indicator of advantages from competition. Larger firms bring with them some degree of spatial monopoly and pricing power. On the other hand larger firms have productivity advantages as a result of scale. We would expect larger markets on average to support larger firms, and possibly, several large firms with national marketing and competitive strategies. This then results in larger firms being associated with agglomeration economies.

2.4.3.2 Public Service Quality and Cost

Second, our agglomeration factors are designed to reflect the impact on productivity and quality of life of the agent missing from our structural equations – the government, as its policy instruments are correlated to population size. Government is responsible for infrastructure and services, and the associated agglomeration factors describe the quality and cost of these services. To some extent, there is an overlap with the previous set of factors, including in particular road and water infrastructure factors used to proxy facility sharing. But this is not a problem, as these are simply two interpretations of the two factors entirely consistent with each other.

The following considers public services for each of the three agents. While a few public services are pure public goods and to some extent used by all three agents, most services are not. This is obvious for service costs, as different agents are subject to different taxes. It is also true for service quality as services have a combination of public good, club, and private good attributes, which vary in importance for different agents. Hence, consider each agent in turn.

Public Service Quality to Consumers: We propose to measure public service quality by the residential property tax rate, *restxr*, i.e. by property tax revenues divided by residential property value. This needs some explanation, as this is not an outcome or even output measure. Indeed, it is not a traditional input measure. While property taxes pay for a number of different services, the one service that has the greatest importance is education. Education is largely a club good, as the service is limited only to the residents of a region. We take the property tax rate as the admission fee for a club and hence an indicator of *preference* for education, and more generally, as a measure of preference for public services. Those with a preference for services take the fee as an indicator of the level of service they will receive, and pay a premium to be close to others with similar service preference. As Tiebout (1956) suggests, a high service fee has to be bundled with a high service level.

Public Service Cost to Consumers: A key part of the cost of public services is the property tax, though in Ohio residents also pay for services through a host of other taxes and user charges, including in particular the sale tax and the income tax. The public service cost here is proxied by the share of property tax in income, *prtxshr*, i.e. the total property tax collected by all types of local government, divided by the total income of consumer-residents. *Quality of Public Services to Traded Good Sector*: This is proxied by two variables, one an indicator of educational service, the other a measure of government operating resources. Educational services are proxied by the 12^{th} grade pass scores 12*gps*, i.e. the average percentage of students who have met minimum State of Ohio scores in reading, writing, math, science and citizenship. Overall resource input is measured by per capita operating expenditures of county governments, *pcexp*. While this is an input variable, there are many instances in the literature, when researchers have substituted input for output measures.

Cost of Public Services to Traded Good Sector: This is approximated by the commercial, industrial and mineral property tax rate, *indtxr*. Firms across counties are assumed to have the same unit cost structure. However, industrial property taxes alter this structure, by imposing a higher or lower than average burden on industries, depending on the county of their location.

Quality of Public Services to Housing Producers: This is proxied by two variables, road density *rdnt*, and by the public supply share of domestic water consumption, *water*. As already discussed, both are expected to decrease the cost to housing suppliers..

Cost of Public Services to Housing Producers: Again, this is approximated by the commercial, industrial and mineral property tax rate, *indtxr*.

2.4.3.3 Other Agglomeration Factors

Here we include two variables, one a measure for the level of human capital, and the other population as a proxy for the many agglomeration factors such as congestion, labor pooling, and improved matching for which no individual proxies are available.

Hunan Capital: Human capital is created in two ways – through local schooling and through migration. The effect of schooling on human capital is measured by 12*gps*, and has already been discussed. The effect of migration is proxied by the percentage of the population 25 years and older with associate's degree or higher. Obviously, this variable also reflects to some extent the effect of local education, though in many rural counties without college, the variable reflects education acquired elsewhere. A higher level of education typically will raise productivity and earnings. Conversely, a larger urban economy attracts a better qualified labor force. The literature suggests that more educated people tend to migrate to larger urban areas for the quality and variety of service offered, and for the better matching of their skills to jobs as a result of the larger job market. These rewards are higher for people with advanced and more specialized skills and represent a feedback from agglomeration characteristics to educational attainment.

Population: Population size, *pop*, can have positive or negative effects. However, since the positive effects have mostly been modeled while the negative effects (pollution, congestion) have not, population captures, at least to some degree, these negative effects. Hence, we expect population to potentially have negative agglomeration effects on productivity and utility. Agglomeration diseconomies have been largely neglected in the NEG literature. However, this means, as we have argued in the introduction, that agglomeration economies and their causes are underestimated – as without modeling the negative effects, one only models net-effects.

2.4.4 Estimation Method

Here we explain the estimation method of the empirical model constructed in the form of a simultaneous system of spatially interrelated equations. We will deal with spatial autocorrelation (SAC) in a simultaneous equations framework. We apply the generalized spatial three stage least squares (GS3SLS) method suggested by Kelejian and Prucha (2004), though an iteration procedure is added.

As the spatial unit of observation is the county and counties are adjacent to each other, there may be SAC in the disturbance terms, as modeled in (2.23) − (2.25). The inclusion of spatial lag terms would partly correct for SAC among adjacent observations, and thus may eliminate SAC in the disturbance terms. But the definite answer to this question should be based on a test of the null hypothesis that there is no SAC for the disturbance terms. Once estimators for the spatial error parameters ρ's are obtained with their asymptotic distributions, the test of the null is straightforward. Unfortunately, however, the asymptotic distributions are not known in many cases,[7] and hence a non-parametric method needs to be introduced to see a tendency of SAC instead. Anselin and Kelejian (1997) suggest that Moran's Index (MI) be used for the test of SAC,

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[7] This is the case with the estimation method used in this chapter, the generalized spatial three stage least squares (GS3SLS). But for a single equation, the GMM estimator's distribution is known; see Kelejian Prucha (2008).

even when the model includes endogenous regressors as in our case. A high positive/negative value of MI implies that the null hypothesis should be rejected and the variable is spatially auto-correlated positively/negatively. We test SAC for each disturbance term of the system of equations in the model, using the residuals from the conventional 3SLS estimation of the model with the spatial error parameters put to zero. The results of the test show that the disturbance terms in the equations are somewhat spatially correlated and the direction of correlation is always positive. Even though the MI's are not significant at the 5 percent, we maintain the spatial auto-correlated disturbances as specified in the model because the MI test is an indirect test of the null and the weak SAC tendency may caused by non-zero values of spatial error parameters.[8]

	Log(*pop*)	Log(*inc*)	Log(*hpric*)
Moran's I	0.050502	0.041392	0.082545
Expected I	-0.011494	-0.011494	-0.011494
Variance	0.004403	0.004377	0.004395
z Score	0.934328	0.799413	1.418541
p-value	0.350135	0.424051	0.156033

[*] The statistics have been computed using ArcGIS with the weight matrix **W** as defined previously.

Table 2.2: Spatial Autocorrelation Test Results[*]

It is not easy to deal with SAC in simultaneous equations models, as the variance-covariance matrix of the disturbance terms is complicated. For single equation models, several methods are used to solve the autocorrelation problem. The spatial econometrics literature widely uses the Cliff-Ord-type spatial autoregressive model that contains spatial lags in the dependent

[8] This will ensure the consistency of the estimators, even if it may compromise efficiency a little bit when the true values of the spatial error parameters are zero. For the comparison purpose, we also report the estimation results for the model without spatial auto-correlation in the disturbance terms in Appendix C.

variable, exogenous variables, and the disturbance term (Anselin, 1988; Anselin & Bera, 1998; Anselin, Florax, & Rey, 2004; Dormann et al., 2007; Kelejian & Prucha, 1998; Kelejian & Prucha, 1999; LeSage & Pace, 2009). The geography literature sometimes uses spatial filtering with eigenvectors of the weight matrix, based on the interpretation that SAC is a result of misspecification (Getis & Griffith, 2002; Griffith, 1996; Griffith, 2000; Patuelli et al., 2009; Tiefelsdorf & Griffith, 2007). When applied to simultaneous equations models however, these single equation methods lead to multiple complications, as shown in the spatial econometrics literature (Henry, Schmitt, & Piguet, 2001; Kelejian & Prucha, 2004; Rey & Boarnet, 2004).[9] While maximum likelihood (ML) estimators have often been used, their asymptotic properties have not been established until Lee (2004) and they are often not feasible for moderate or large size samples (Kelejian & Prucha, 1999). Kelejian and Prucha's (2004) suggests a computationally simpler estimation method that combines two (or three) stage least squares with the generalized moments method (GMM) to estimate simultaneous systems with spatial lags and spatial errors. Subsequent comparative studies on the ML and GMM estimators show that Kelejian and Prucha's method is better in computational simplicity and applicability to extended models (Bivand, 2009; Kelejian & Prucha, 2008; Walde, Larch, & Tappeiner, 2008).

In this paper, we adopt Kelejian and Prucha's (2004) method to estimate the simultaneous system of spatially correlated equations and iterate the procedure to obtain better estimates of spatial error parameters. The estimation procedures in Kelejian and Prucha's are as follows:

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[9] To our knowledge, spatial filtering has never been used for the estimation of a SEM.

i) Initial 2SLS: Estimate the model using the two stage least squares (2SLS) to obtain residuals as estimators for the disturbance terms, assuming that spatial error parameters equal zero ($\rho_1 = \rho_2 = \rho_3 = 0$).

ii) GMM: Using the residuals from Step i), apply a generalized moment method to get a consistent estimator for the spatial autoregressive parameters, ρ's.

iii) GS2SLS: Using the estimates for ρ's from Step ii), apply a generalized spatial 2SLS method to get a limited information estimator, which does not take into account potential cross equation correlation, for regression parameters.

iv) GS3SLS: Using the residuals from Step iii), estimate the cross equation correlation, and the results are again used to estimate the system using a generalized spatial 3SLS estimation, as usual in 3SLS. In this sense, this gives us a full information estimator that takes into account potential cross equation correlation.

See the original paper for the mathematical expressions and asymptotic properties of the estimator. The GS3SLS estimator is obviously better than the initial 2SLS estimator, and thus it leads to a better estimator for the spatial parameters if one iterates the procedures from Step ii) through Step iv). We iterate this process by replacing the 2SLS residuals in Step ii) by the GS3SLS residuals from Step iv) until the values of spatial parameter estimates converge.[10]

Lastly, let's look at the endogeneity of the variables used in the model. The model includes many endogenous variables in the econometric sense, as mentioned in Section 2.3.

[10] Since there is no built-in program for GS3SLS in the existing econometric and statistical packages, we programmed it using Stata® 11 based on the Kelejian and Prucha's (2004). In our estimation, the convergence criterion for the iteration is that the root mean squares of the three parameters is smaller than 0.001

Besides the three simultaneously determined endogenous variables log(*pop*), log(*inc*), and log(*hpric*), agglomeration factors are all potentially endogenous variables in the sense that they may be correlated to the disturbance terms. The endogeneity of each agglomeration factor is tested using the Durbin-Wu-Hausman test, as applied to a test of a subset of the regressors; see Baum, Schaffer, and Stillman (2003) for technical details. For the eleven agglomeration variables for which we expect to find endogeneity based on theoretical and plausibility arguments, we find endogeneity for ten in one or more equations of the model at the 30 percent level of significance. The 30 percent level of significance is used to be on the conservative side. When using instruments for a variable that was incorrectly classified as endogenous when in reality it was exogenous, we lose efficiency but estimates remain consistent. This is more important than a loss of consistency caused by incorrectly accepting a variable as exogenous, when in fact it is endogenous.

Table 2.3 shows the variables used. Three variables are endogenous in the structural sense that each is modeled through a separate structural equation: *pop*, *inc*, and *hpric*. Another 11 variables represent agglomeration factors, of which only the endogeneity of *lqman* proves statistically not significant. All the ten variables are modeled using the same set of instruments. In addition, three variables represent spatial lag variables for the three endogenous variables – $\overline{\log(pop)}$, $\overline{\log(inc)}$, and $\overline{\log(hpric)}$, computed for each county as the county average for adjacent counties as explained earlier. The remaining 21 variables are exogenous agglomeration attributes, such as snow fall, weather attributes, distance to the nearest airport and others. Some of them are not included in the model but used just as instrument variables (IVs).

	RHS			
LHS	Endogenous Vars. (Structural Sense)	Endogenous Vars. (Econometric Sense)	Exogenous Vars.	Instrument Vars.
log(*pop*)	log(*inc*), log(*hpric*), $\overline{\log(pop)}$	*prtxshr*, log(*szret*), *restxr*, log(*pctrf*)	*snow*, log(*area*), *greatlakes*, *jantemp*	*crime*, log(*crime*), *lqcns*, log(*snow*), *vacn*, *lqret*, *nofreez*, log(*nofreez*) + 1st and 2nd order lag variables of all the exogenous and instrumental variables
log(*inc*)	log(*pop*), $\overline{\log(inc)}$	*educ*, *indtxr*, log(*pcexp*), 12*gps*	*age*, *agesq*, *unemp*, *lqman*, *distair*	
log(*hpric*)	log(*inc*), log(*pop*), $\overline{\log(hpric)}$	log(*rdnt*), *water*, *indtxr*	log(*area*), *hyear*, *hroom*	

Table 2.3: Structure of the Model

The IVs are *crime*, log(*crime*), *lqcns*, log(*snow*), *vacn*, *lqret*, *nofreez*, log(*nofreez*), and the first and second order lag variables of all the exogenous and instrumental variables. All these variables are somewhat correlated to the agglomeration factors but are supposedly given exogenously.[11] The lags of all the exogenous and instrument variables are also included as IVs in order to instrument the three spatial lag terms in the model, as suggested by Kelejian and Prucha (2004).

[11] One may think that the variables of crime rate and vacancy rate, *crime* and *vacn*, are endogenous, but an endogeneity test suggest that they end up not being endogenous. This is due to that fact that the two variables are determined by both generation and enforcement, or both supply and demand and thus only one side does not fully determine them. For instance, crime may occur frequently in a highly populated region, but the police service is also good in that region. So the net effect of population size is ambiguous. The same argument can be applied to housing vacancy rate.

2.5 Empirical Results

2.5.1 Parameter Estimation Results

The final structure of the model to be estimated is summarized in Table 2.3. The system consists of three structural equations describing the representative agents' behaviors. The first equation represents the individual's consumption behavior, and the second and third the firms' production behavior in the two sectors. The selection of explanatory variables in each equation is a result of plausibility arguments first and empirical confirmation second. The following justifies the selection for variables not already discussed earlier.

First, adjacency to the Great Lakes, *greatlakes*, significantly impacts consumer's utility but not a firm's productivity, and hence has been deleted from the traded good and housing sectors. This suggests that the Great Lakes bestow leisure and amenity values to consumers, but that their historical advantage to the traded good sector in the form of access to ports and their potential disadvantage in the form of high union wages are no longer important or cancel out.

Second, snow and January temperature also appear in the worker-consumer equation only, and proved not significant elsewhere. The reason again likely is that weather related variables have a greater impact on quality of life than productivity, though with a greater number of observations, these variables certainly might be significant in the housing sector, as weather condition may affect construction costs.

Third, the variables related to human resources, *educ*, 12*gps*, and *age* with its square term, are significant in the traded good sector but not the housing sector. Traditionally, the construction sector values skills acquired on the job, but not related to higher education. As to the worker consumer, higher education leads to higher income, but its effect is already controlled for by including income in the model.

Fourth, the variables related to the basic infrastructure, *rdnt* and *water*, are included only in the housing sector equation, but not in the traded good sector equation. Subdivision regulations in Ohio require that developers provide basic infrastructure such as roads, water and sewage systems if they do not exist, potentially raising the cost of housing production. In other sectors however, these systems typically represent a small share of production costs, and hence turn out to be not significant.

Fifth, after controlling for population, county area is inversely related to density, and is included in the housing and worker-consumer equations. A greater area would signify a smaller density and hence decreased congestion but potentially smaller variety of services, making its sign difficult to determine. Being not significant, the variable was deleted from the traded good sector.

The full results of the iterative GS3SLS are reported in Table 2.4. The table shows the estimates of the coefficients for the three structural equations with inference statistics. For a comparison purpose, we also report in Appendix C the results of the 3SLS estimation for the model without spatial errors as SACs in the disturbance terms are not high. Note that the estimated parameters in the two models are very similar, which suggests the robustness of the estimation.

LHS variable	RHS variable	Estimate	Std Err	t Value	Pr > |t|
log(*pop*)	log(pop)lag	0.3915853	0.091401	4.2843	0.0001
	log(inc)	3.129124	0.465856	6.7169	0.0000
	log(hpric)	-1.13344	0.348607	-3.2513	0.0017
	prptxshr	-27.73352	11.03123	-2.5141	0.0140
	restxr	0.0882298	0.010298	8.568	0.0000
	log(szret)	0.7353888	0.332106	2.2143	0.0298
	log(pctrf)	-0.91053	0.205864	-4.423	0.0000
	greatlakes	0.4594739	0.163706	2.8067	0.0064
	log(area)	1.311045	0.221379	5.9222	0.0000
	snow	-0.00881	0.003906	-2.2556	0.0270
	tempjan	0.0646903	0.022315	2.899	0.0049
	constant	-30.0268	3.873981	-7.7509	0.0000
	R-squared	.8604	Adjusted R-Squared		.8401
	$\hat{\rho}_1$	.1149	$\hat{\sigma}_1$		.1324
	ADEF	1.0364	A1NEF		0.0931
log(*inc*)	log(inc)lag	0.1260172	0.08576	1.4694	0.1458
	log(pop)	0.0211475	0.009848	2.1473	0.0350
	indtxr	-0.0036264	0.001119	-3.241	0.0018
	log(pcexp)	0.072458	0.041457	1.7478	0.0845
	educ	1.507873	0.131409	11.475	0.0000
	12gps	0.0063145	0.001802	3.5035	0.0008
	lqman	0.0376702	0.011665	3.2293	0.0018
	log(distair)	-0.0006734	0.000401	-1.6774	0.0976
	age	0.0858956	0.030535	2.813	0.0062
	agesq	-0.0009349	0.00044	-2.1247	0.0369
	unemp	-0.0178829	0.009852	-1.8152	0.0734
	constant	6.137866	0.84879	7.2313	0.0000
	R-squared	.9117	Adjusted R-Squared		.8989
	$\hat{\rho}_2$	.1979	$\hat{\sigma}_2$		.0025
	ADEF	1.0032	A1NEF		0.0256
log(*hpric*)	log(hpric)lag	0.1962817	0.078801	2.4909	0.0149
	log(pop)	0.1434769	0.028278	5.0738	0.0000
	log(inc)	0.5065929	0.098699	5.1327	0.0000
	indtxr	0.0020221	0.001581	1.2787	0.2048
	log(rdnt)	-0.3006243	0.066904	-4.4934	0.0000
	water	-0.2188807	0.060489	-3.6185	0.0005
	hyear	-0.0115218	0.001168	-9.8687	0.0000
	hroom	0.191342	0.037453	5.1088	0.0000
	log(area)	-0.1150436	0.052531	-2.19	0.0315
	constant	2.902355	1.150041	2.5237	0.0136
	R-squared	.9137	Adjusted R-Squared		.9037
	$\hat{\rho}_3$	.2213	$\hat{\sigma}_3$		.0045
	ADEF	1.0081	A1NEF		0.0412

Table 2.4: Full Regression Results for the Structural Equations

As a first test of the plausibility of the model, we compute and examine the parameters of the utility and production functions, such as the housing expenditure share and the factor cost shares in housing production. The estimates of the parameters for the utility and housing production functions are shown in Table 2.5. Note that the parameters for the production function of the traded good sector, α_1, β_1 and γ_1 cannot be estimated from the model because the equation for that sector does not differentiate returns to the three factors separately but combines them into a single income. Also, we need an estimate for the income share of wage ϖ to derive the parameters of the housing production function. This is approximated as ϖ = .678, which comes from the REIS income data for the state of Ohio in 2000.

$1-\hat{\theta}$	$\hat{\theta}$	$\hat{\alpha}_2$	$\hat{\beta}_2$	$\hat{\gamma}_2$
0.3622	0.6378	0.1032	0.3078	0.5890

Table 2.5: Estimates of Utility and Housing Production Functions' Parameters

The results of the estimation provide initial evidence that the model results are reasonable and plausible. First, the housing expenditure share is about 36 percent. This is significantly higher than the share in Ohio, which we attribute to the fact that housing price represents not only housing cost but also the cost of other non-traded goods and services. Second, the land cost share in housing production is estimated to be about 10 percent or half the value suggested in the real estate and urban economics literature (Roback, 1982). This is not unreasonable however, as there is evidence that the Midwestern share is lower than the US average, and 48 of 88 Ohio's counties are non-metropolitan with small populations with low land rents. They account for just 19 percent of the population but 55 percent of the county observations, and hence rural households are overrepresented. The cost share estimates for labor and capital in housing production are 31 percent and 59 percent, respectively, which are also quite reasonable.

2.5.2 Values of Agglomeration Factors

The effects of an agglomeration factor on an individual's utility and a firm's productivity can be calculated from the estimated model. Using the parameters estimated above and the mean value of the variables, one can compute the expected implicit values of the agglomeration factor. In the case of worker-consumers, implicit prices are expressed as per capita income equivalents. In the case of the traded good and housing sectors, gains take the form of productivity growth or decline, which can be expressed in terms of compensatory changes in factor payments that leave sector unit cost unchanged. Applying the sector share to sector savings yields the effect on average county income. Cost elasticities with respect to agglomeration factors are also shown in Table 2.6. In addition, we are able to compute implicit prices of each agglomeration factor for neighboring counties, using the spatial lag term in the three structural equations. These results are not available elsewhere in the literature, though the presence of spatial autocorrelation in similar research elsewhere makes it clear that these effects exist. Again, the effects are expressed as per capita gains to worker-consumers and sector workers, though in this case they are the consumers or sector workers in an average neighboring county; see Appendix B for the computation method. The results are shown in Table 2.7. Note that the values in this table are estimates for which significance is not established individually. They are the product of own-county effects, for which significance has been established, and the neighborhood effect as measured by A1NDR (for each of the three dependent variables) which is also significant. However, significance has not been established for each of the products individually, as this would require a spatial lag term for each individual variable. The only exception is the amenity value of population size, for which an individual lag term has been estimated as it is both an agglomeration factor and dependent variable in the model.

Hence, consider the estimated values of individual variables, organized according to the causes of agglomeration, second the quality and cost of services, third other agglomeration attributes, and lastly neighborhood effect.

Factors			Value Imputation of Consumers	Cost Changes for Firms by Sector: Traded Good $ /worker	Traded Good elasticity	Housing $ /worker	Housing elasticity
Agglomeration Factors							
Causes of agglomeration	0.1 increase in lq for manufacturing	*lqman*	–	$98.8	-0.402%	–	–
Causes of agglomeration / Services	1% increase in road density	*rdnt*	–	–	–	$146.0	-0.272%
Causes of agglomeration /Services	1% increase in pub. supply share in domestic water	*water*	–	–	–	$82.0	-0.153%
Causes of agglomeration	1% decrease in per capita traffic volume	*pctrf*	$71.6	–	–	–	–
Causes of agglomeration	1% increase in retail size	*szret*	$57.8	–	–	–	–
Quality of services to consumers	1% increase in residential property tax rate	*restxr*	$297.9	–	–	–	–
Cost of services to consumers	1% increase in property tax share in income	*prptxshr*	-$57.5	–	–	–	–
Services / Human Capital	1% increase in per capita County gov't expenditure	*pcexp*	–	$19.0	-0.077%	–	–
Quality of services to traded good sector	1% point increase in 12th grade scores	12*gps*	–	$165.8	-0.674%	–	–
Cost of services to the two sectors	1% increase in industrial property tax rate	*indtxr*	–	-$45.6	0.185%	-$47.2	0.088%
Human capital	1% point increase in associate's degree	*educ*	–	$397.7	-1.617%	–	–
Residuals	1% increase in population	*pop*	-$75.9	$5.54	-0.023%	-$13.81	0.026%
Other Attributes	Doubled in distance to international airport	*distair*	–	$17.6	-0.072%	–	–
	Great Lakes location	*greatlakes*	$3,612.6	–	–	–	–
	1% increase in land area	*area*	$103.1	–	–	$55.9	-0.104%
	1% increase in annual snow accumulation	*snow*	-$16.5	–	–	–	–
	1 F increase in January average temparature	*jantemp*	$508.6	–	–	–	–
	1 year increase in age	*age*	–	-$435.3	1.769%	–	–
	1% point increase in unemployment rate	*unemp*	–	$463.9	-1.886%	–	–
	1 year increase in housing age	*hyear*	–	–	–	$556.6	-1.036%
	1% increase in housing size	*hsize*	–	–	–	-$540.4	1.006%

Table 2.6: Own Values of Agglomeration Factors

Factors			Value Imputation of Consumers	Cost Changes for Firms by Sector: Traded Good $ /worker	Traded Good elasticity	Housing $ /worker	Housing elasticity
Agglomeration Factors							
Causes of agglomeration	0.1 increase in lq for manufacturing	*lqman*	–	$2.51	-0.010%	–	–
Causes of agglomeration / Services	1% increase in road density	*rdnt*	–	–	–	$5.97	-0.011%
Causes of agglomeration /Services	1% increase in pub. supply share in domestic water	*water*	–	–	–	$3.35	-0.006%
Causes of agglomeration	1% decrease in per capita traffic volume	*pctrf*	$6.4	–	–	–	–
Causes of agglomeration	1% increase in retail size	*szret*	$5.2	–	–	–	–
Quality of services to consumers	1% increase in residential property tax rate	*restxr*	$26.7	–	–	–	–
Cost of services to consumers	1% increase in property tax share in income	*prptxshr*	-$5.2	–	–	–	–
Services / Human Capital	1% increase in per capita County gov't expenditure	12*gps*	–	$4.22	-0.017%	–	–
Quality of services to traded good sector	1% point increase in 12th grade scores	*pcexp*	–	$0.48	-0.002%	–	–
Cost of services to the two sectors	1% increase in industrial property tax rate	*indtxr*	–	-$1.16	0.005%	-$1.93	0.004%
Human capital	1% point increase in associate's degree	*educ*	–	$10.1	-0.041%	–	–
Residuals	1% increase in population	*pop*	$6.1	$0.14	-0.001%	-$0.56	0.001%
	Doubled in distance to international airport	*distair*	–	-$0.45	0.002%	–	–
	Great Lakes location	*greatlakes*	$324.3	–	–	–	–
	1% increase in land area	*area*	$9.3	–	–	$2.28	-0.004%
	1% increase in annual snow accumulation	*snow*	-$1.5	–	–	–	–
Other Attributes	1 F increase in January average temparature	*jantemp*	$45.7	–	–	–	–
	1 year increase in age	*age*	–	$11.0	-0.045%	–	–
	1% point increase in unemployment rate	*unemp*	–	-$11.9	0.049%	–	–
	1 year increase in housing age	*hyear*	–	–	–	$22.9	-0.043%
	1% increase in housing size	*hsize*	–	–	–	-$22.0	0.041%

Table 2.7: Neighbor Values of Agglomeration Factors

2.5.2.1 Causes of Agglomeration

Specialization Economies: The average specialization index for manufacturing is 1.22, with a minimum value of zero and a maximum of 2.72. An increase in manufacturing specialization by 0.1 (an 8 percent increase at the mean) raises productivity in the traded good sector by 0.4 percent, equivalent to $98.8 per sector worker on average.

Facility Sharing: A 1 percent increase in road density raises housing productivity by 0.272 percent, or by $146 per construction worker.[12] A 1 percent increase in the share of public water provision raises housing productivity by 0.153 percent, or by $82 per construction worker. In both cases, the mean effect on county income of course is much smaller, $8.3 and $4.7 per resident respectively, given the 5.7 percent employment share of the construction sector. These values are plausible, given the share of public supply of water.[13]

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[12] Even if productivity gain is smaller than in the traded good sector, the compensatory wage is larger because the labor share in total factor cost is smaller (30.8 percent).

[13] For the average county, the public sector supplies 77 percent of domestic water. A 10 percent increase in this supply would raise this share by 7.7 percentage points and result in cost savings of 1.53 percent. For a switch of 7.7 percent of housing units to generate savings of 1.53 percent spread over all housing units, the switched units must each have generated savings of 19.87 percent (=1.53/0.077). Given an average (median) housing price of $94,323, these are savings of $18,742. This may be on the high side as a cost estimate for a privately supplied water and sewerage system, but is of the correct order of magnitude. Areas without public water supply typically also lack a public sewer system, so the impact estimate likely reflects the cost of both. The cost of private water supply typically consists of a well, pump, and water

Variety: As argued earlier, increased density raises variety, and reduces per capita travel distance. A 1 percent decrease in per capita traffic flow is associated with an average amenity rise of $71.6 per worker consumer. Note that this is a net effect, diminished by the cost of increased congestion and the potentially lower utility associated with switching from private to public transportation – though these individual effects cannot be further disaggregated.

Advantages from Competition: As argued earlier, increased competition leads to survival of larger retailers. A 1 percent increase in retail size generates an increase in amenities of $57.8 per consumer, presumably reflecting the reduced prices and greater in-house variety of national retail chains. This result is in line with Fu's (2007) study on the effect of Wal-Mart noted in Section 2.

2.5.2.2 Public Service Quality and Cost

Public services impact residents and firms both through a change in quality and cost. Ideally, this permits calculating net benefits, though the nature of available proxies makes it likely that this would over-interpret the results.

Quality of Public Services to Consumers: Residential service quality is proxied by the residential property tax rate. A 1 percent rise in service quality is valued at $297.90 per capita, i.e. residents are willing to accept an income decrease of close to $300 when moving into a county with a 1 percent higher service quality. This seems high, particularly when compared to a 1 percent increase in service cost. Most likely, a high property tax rate serves as a sign to potential newcomers of the importance existing residents attach to services. Those with a preference for

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tank, or the connection to another existing private system. Private septic and other systems require additional expenditures on land, as codes require a minimum 1 acre lot size.

services take it as an indicator of the type of service they will receive, and pay a premium to be close to others with similar service preference. There is also a possibility that high property taxes are suggestive of the quality of the school system and the importance others in the area attach to schooling. In that sense, the high implicit price is suggestive more of a club fee required to enter the area and the attributes of the club including its members, than of the service quality alone.

Cost of Public Services to Consumers: The average property tax share in income is 2.64 percent or a per capita property tax burden of $765.60 at an average per capita income is about $24,600. A 1 percent increase raises property taxes by $7.65, but residents demand $57.50 in increased income to settle in this county. This seems high, but can be attributed to two factors: First, property tax proxies other local non-property tax expenditures, including higher income and sales taxes. Second, residents may have an aversion to a higher tax share, requiring compensatory income payments exceeding the actual cost of the tax increase.

Quality of Public Service to Traded Good Sector: Two variables proxy service quality. First, a 1 percentage point increase in 12^{th} grade scores reduces cost in the traded good sector by 0.674 percent, or by $165.8 per sector worker. Second, a 1 percent increase in county operating expenditures reduces cost by 0.077 percent or $19.0 per sector worker. Both effects are significant and of the right sign. The impact of county expenditures seems too small to be important to firms. However, this is a macro model, and while the impact is small to the average firm, it may be quite important to some firms.

Cost of Public Service to Traded Good Sector: A 1 percent increase in industrial property taxes raises cost by $45.6 per sector worker. This seems plausible. Given an average income per worker of 24,600, a capital factor share 32.25 percent, an average millage rate of 48.1 per mil, and assuming for illustration a 5 percent real interest rate and average capital life of 10 years, capital income per worker is $7,934, capital is valued at 61,264, and annual property taxes would amount to $2,947, and a 1 percent increase in taxes therefore is $30 per worker per year, or roughly in line with the estimated cost of $45.6. The plausibility of the results is also confirmed by looking at the coefficient of the variable, *indtxr*. The theoretical model (2.10) suggests that the coefficient should be ϕ if the industrial property tax is all tax the firm has to pay. But the estimated coefficient is 3.8 times greater than this. As in the case of the worker consumer, the difference can be attributed to the fact that the tax rate here reflects all local taxes rather than only industrial property taxes; see also the model formulation.

Quality of Public Service to Housing Sector: The two variables have already been discussed in the section on facility sharing. As noted there, savings from public road density and water investment are the result of reduced subdivision development cost. Note however, that the estimated 0.27 percent cost reduction as a result of a 1 percent increase in road density may overestimate real cost savings, as an increase in road density lowers housing price through another channel: A high road density lowers unit transportation cost and hence land and housing prices. It is impossible to separate this effect from production cost savings.

Cost of Public Service to Housing Sector: The cost is estimated by the industrial property tax millage rate, which is not significant.

2.5.2.3 Other Agglomeration Factors

Human Capital: An increase by 1 percentage point in the associate's degree share improves trade sector productivity by 1.6 percent. This is plausible, given the evidence of micro studies in labor economics. A 1 percentage point increase in associate's degrees corresponds to an average 0.076 years rise in years of schooling.[14] This implies that an additional year of schooling leads to 21.3 percent increase in income. This is a plausible result, given estimates in the literature of a return to an additional year of schooling ranging from 4.0 percent to 18.5 percent; see Ashenfelter and Rouse (1999) for a review. While our estimate lies slightly above this range, our model estimates the aggregate impact of schooling, and hence includes the effect of increased capital and labor productivity and its effect on both wage and capital rent; see Breton (2009) for the difference between macro- and micro-effects of schooling.

Population: Population in our case is a residual agglomeration factor. Since positive effects have been largely accounted for, it will reflect mainly the negative effects of congestion, pollution, and other similar diseconomies associated with rising density. This is confirmed by the results which show a 1 percent increase in population generates disamenities equivalent to in annual income of $75.9.

Comparable results exist in the literature only for own area amenity effects. While the impact of $75.9 may seem small, it is larger than other estimates in the literature. Roback (1982) estimates that disamenity due to an increase of population by 10,000 is equivalent to an income decrease of $1.5 per year, which translates into $0.19 per year for a 1 percent increase of Ohio counties' average population. There are reasons why our estimate is so much higher than her estimate. As discussed earlier, our estimates are gross impacts, while those in the literature are net effects. They already net out positive effects due to agglomeration, whereas our model controls for the effects of other agglomeration factors. Another reason for the difference between

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[14] This translation comes from a simple regression of the variable *educ* on the average years of schooling in each county with the data set for Ohio. The regression results is summarized as $duc = -1.443 + 0.1316\ schyrs + \epsilon\ (R^2 = .8946)$, where *schyrs* is 'years of schooling' and ϵ is the error term.

Roback's estimate and ours may also be attributed to a bias in her estimation that results from her OLS estimation. Since population size is obviously endogenous, OLS estimation must be biased. Our estimate also differs from Tabuchi and Yochita's (2000) estimates, which have the opposite sign. They argue that the net effect of doubling city size in Japan raises amenities by the amount equivalent to a 7-12 percent increase in real wage. This may be attributed again to the difference between net and gross effect, and possibly, cultural differences between Japan and the U.S.

Consider next the impact of population on the traded good and housing sectors. A 1 percent increase in population leads to savings in the traded good sector of 0.023 percent (equivalently, an income rise of $5.54 per sector worker) and to a cost increase of 0.026 percent (equivalently, an income decrease of $13.81 per sector worker) in the housing sector. These estimates are comparable to estimates in the agglomeration economies literature (Eberts & McMillen, 1999; Wheaton & Lewis, 2002). Elasticities reported in the literature imply that doubling city size raises productivity by 2-10 percent, a range that covers our results for the traded-good sector. The negative effect on the productivity of housing sector is consistent with theory, which tells us that marginal cost of construction increases with rising building height or increased population density.

2.5.2.4 Control Variables

Finally the model includes as control variables a number of other regional attributes not strictly associated with the size of an agglomeration. Two are briefly mentioned here. Others are not discussed but have the correct sign and plausible orders of magnitude.

Great Lakes Adjacency: The Great Lakes dummy has a positive impact on individual's utility valued at $4,433. One reason undoubtedly is that the Great Lakes region provides leisure and recreational values not found elsewhere in Ohio. Another reason perhaps is lingering regional legacies. Traditionally, the region was part of an industrial cluster associated with steel, rubber and automobile manufacture with access to international shipping that may have given it extra productivity and higher income and non-income benefits. While income effects are already accounted for other benefits are not. Note however, that Great Lakes adjacency no longer offers firms any significant productivity gains. The variable was not significant in either of the other two equations. Hence, the legacy of past prosperity may continue to positively impact individuals' amenities even after underlying productivity gains have disappeared.

Distance to Nearest International Airport: The variable has been introduced as a way to identify the competitive advantage of counties in national and international markets resulting from differences in transport cost. The variable is significant at the 10 percent level. The average number of miles is 47 miles. Doubling distance to the nearest international airport increases the cost in the traded good sector by 0.072 percent, requiring a compensatory reduction in income of $17.6 per sector worker. While the effect seems small, this is the result of averaging as not all firms in the traded good sector trade at the national or international level or depend on traded inputs.

2.5.2.5 Neighborhood Effects

Finally, consider the impact of the agglomeration factors on neighboring counties. While our study confirms findings in the literature that suggest weak spillovers across regions on the production side, it suggests that there are strong spillovers on the consumption side. The results suggest that there are significant neighborhood effects, which for worker-consumers are 9.0 percent of the own effect and for the traded good and housing sectors respectively 2.6 percent and 4.1 percent. The amenity neighborhood effect of population size is 8.0 percent of its own effect. However, the trade-good effect is significant only at the 15 percent level.

The high neighborhood effects on the consumption side are remarkable, as the agglomeration literature usually argues that agglomeration economies decay rapidly over space as reviewed in Section 2. This result however, is consistent with our intuition that for metropolitan residents, county boundaries are often not important barriers as they commute to neighboring counties for work and shopping. On the other hand, the weak neighborhood effect on the production side is in line with the literature. The latter finding may however, be impacted by the nature of our observations. Trade-good firms in rural counties do not depend much on outside business services, and largely rural counties make up more than half the counties in Ohio. It would be interesting in the future to take a sample of counties in metropolitan areas and to examine traded good sector spillovers between suburban and central counties.

Note that spillover effects are specified and thus tested for significance as a group and not individually; see the model specification. Even while neighborhood effects are significant for each equation, this does not imply that each variable has significant spillover effects when tested individually. Hence it is not appropriate to discuss specific values of neighborhood effects for individual agglomeration factors, except for the amenity spillovers related to population; see the note related to Table 2.7.

Amenity Effect of Population: The most interesting finding here is that neighborhood effects of a population increase are positive, whereas its 'own-county' amenity effect is negative. The average consumer in a neighboring county enjoys a $6.1 amenity gain as a result of the 1 percent population increase in an adjacent county. People dislike growth in their own backyard and must be compensated by a $75.9 increase in income; but they quite like the increased opportunities associated with a population increase nearby, and hence accept a decrease in income as a result.

Further, it is interesting to take a typical central metropolitan county, and consider its relationship with surrounding suburban counties. Looking at a metropolitan region in isolation, and neglecting spillovers to rural areas as being an order of magnitude smaller, assume that half of the region's population resides in the central county and the other half in a ring of eight suburban counties. Then the amenity losses to the central county residents from a 1 percent population increase in its own county are over 12 times as high as the amenity gains experienced collectively by suburban residents. On the other hand, in recent years population increases have been mostly in suburban counties while the central county's population stagnated or declined. As a result, suburban quality of life declined, while central county quality of life increased.

Other Amenity Effects on Worker Consumer: Neighboring counties benefit from other agglomeration factors. An increase in retail size, *szret*, a decrease in traffic volume, *pctrf*, and an increase in the property tax rate, *restxr* possibly generate amenity gains in neighboring counties. The large size and product variety of shopping centers creates catchment areas that extend beyond county boundaries. Services such as parks, libraries and well maintained streets benefit customers from beyond county limits; and safer neighborhoods associated with better policing reduce negative spillovers from crime. There are also spillovers from the cost of services to the extent that people commute to neighboring jobs and are subject to their local income taxes.

In passing we note that exogenous agglomeration attributes also have neighborhood effects. These include the Great Lakes location, climate variables and others. Specifically, neighbors to Great Lake counties experience amenities, whether or not they have their own access to the shoreline. In either case, accessibility to shoreline opportunities rises. Similar arguments hold for climate variables.

Neighborhood Productivity Effects on Traded Good Sector: The neighborhood effects in aggregate are small – just 2.6 percent of own-county effects, and not much statistically significant, though neighborhood effects of some agglomeration factors might well be significant when individually testable. This would likely be true for human capital variables such as the associate's degree share, *educ*, and 12th grade passing score, 12*gps*, as workers often commute beyond county boundaries. It would likely also hold for manufacturing specialization, *lqman*, as firms benefit from input-output relations within metropolitan regions.

Neighborhood Productivity Effects on Housing Sector: The neighborhood effects are larger than those on the traded good sector – 4.1 percent of own-county effects, and statistically significant. But it is not straightforward to explain productivity spillovers from neighboring water and road supply. However, productivity spillovers from neighboring population size or a greater amount of neighboring land are plausible.

2.6 Policy implications

The empirical estimates suggest several ways to raise firm's productivity or consumer's quality of life – though of course, the general equilibrium framework means that all such impacts are fleeting. To remain competitive, local areas must constantly innovate. Any substantial advantage in productivity or quality of life is likely to be eroded, through migration, business expansion or contraction, and feedback effects from agglomeration factors.

Policy results emerge at many levels – first in terms of our understanding of the nature of agglomeration economies; second at the national level, where policy makers discuss spatial strategies and the type of cities they favor, secondary cities or large agglomerations; third at the level of a region such as Ohio, where local economic development (LED) planners must identify ways to attract businesses to Ohio, make site recommendations for potential investors, or allocate investment dollars to infrastructure projects in different parts of the state; fourth, at the level of the individual local area, where planners are asked to reverse decline or strengthen competitiveness; and finally, at the level of the individual firm that must decide where to locate. In general, the same empirical results lend themselves to interpretation at any of these levels.

2.6.1 General Findings

Significance of Agglomeration Factors: First, the paper confirms the existence of agglomeration economies, but shows that when agglomeration factors are accounted for, population size raises firm's productivity, but decreases a worker-consumer's quality of life. The negative effect of increased population size in the form of pollution, congestion, and other negative effects associated with size outweigh unexplained positive effects. Of course, this is in part the result of accounting for choice and variety through other agglomeration factors. Moreover, the size of the negative effects is much larger than estimates elsewhere in the literature. Where voters have a choice, they can be expected to back growth control initiatives, particularly if restrictions are limited to population but exclude the jobs provided by the traded good sector.

City Size Strategies: Second, the paper's findings do not support a focus on either small or large cities. The findings neither support secondary city policies that hope to redirect urban growth to smaller cities, away from larger metropolitan areas. Nor does it support a policy focus on large metropolitan areas as a source of unlimited untapped agglomeration economies. This is the result of the underlying spatial equilibrium assumptions that suggest the co-existence of localities of vastly different sizes, all providing similar utility to households and all allowing firms to compete in national or international markets. The findings show that such a framework is plausible and that the system of three equations provides plausible estimates consistent with such a system. Strictly speaking of course, the model is a behavioral model, and thus it cannot tell us about optimal city size.

The bottom line is that looking at changes in population in isolation (holding all agglomeration factors constant), an increase in size will result in amenity losses to the population and in productivity increases to the traded good sector. At average agglomeration factors, a 1 percent increase in size will lead to a net loss of $71.5 in per capita income, i.e. amenity losses exceed productivity gains. However, this is the case because a host of other agglomeration factors, largely associated with positive effects on productivity and amenity, have already been accounted for. For policy makers, the idea is to develop a package of policies that temporarily, say for a few years or even a few decades, moves the city ahead of its competitors, and allows temporarily its residents to enjoy higher amenity values than are available elsewhere.

Local Economic Development (*LED*) *Policies*: Third, the paper estimates the gross rather than net effects of agglomeration factors, and it does so for a large number of agglomeration factors including population size. This affects policy analysis in several ways. Without it, two cities of similar size would be thought to provide similar worker-consumer amenities and productivity. Instead now, one looks at the underlying composition of agglomeration factors and may come to entirely different conclusions. In addition, the order of magnitude of elasticities matters. As the estimates show, the elasticity of a factor such as population size may change by an order of magnitude relative to earlier research. Hence, in the past a factor such as population may have been statistically significant but not important in its size, this is no longer the case. Linking amenities and productivity to a variety of factors also enriches the policy analysis. LED policy recommendations for individual cities usually seek to identify weaknesses in a city's competitive position through a mixture of quantitative and qualitative analysis. The findings in this paper will not change this, in that qualitative analysis still matters, but it provides a more rigorous basis for the conclusion that many factors have an impact on productivity and amenities.

Also, the paper identifies some of the underlying causes for agglomeration economies. This is of interest since the presence of these causes has been postulated in the literature, but empirical evidence of their presence or size remains slim. Local economic development planners mostly make their arguments based on qualitative arguments. They may argue about the importance of manufacturing localization as a source of economies, or about the increased competitiveness and lower prices associated with greater size. The findings provide additional evidence that these effects exist. It also suggests that some of these effects – even though they exist – are quite small, and hence may not be worth pursuing in a policy framework.

Neighborhood Effects: Fifth, the results show that neighborhood effects are strong, particularly for worker consumers, where spillovers to neighboring counties are about 8-9 percent of own-county effects. This suggests that free rider problems exist in intra-urban or intra-metropolitan relations between suburbs and a central city, or between suburbs and rural surroundings. These facts lend themselves as much to an argument for or against metropolitan government, depending on who makes the argument. At the state level, one may point to the efficiencies that could result by internalizing externalities, at the local level they can be used to take advantage of free rider opportunities.

2.6.2 Detailed Implications

Public Services: First, decisions on public services matter to the competitiveness of a city, both in terms of amenities to residents and productivity gains to firms. The amenity value of improved services is particularly high, and individuals pay a premium in foregone income to be close to others with similar service preference, i.e. similar willingness to tax themselves highly. A high property tax rate does not imply high out of pocket costs, but is likely seen as an indicator of service quality. On the other hand, the findings also confirm a certain level of tax aversion, as compensatory income payments exceed property tax cash outlays. An additional interpretation of this finding is that the property tax share in income is a proxy for all local taxes and hence, high compensatory payments reflect the cost of all local taxes. Either way, the evidence provides no support for the kind of property tax reductions favored in California.

Firms also benefit from public services, including in particular from good schooling, as suggested by high productivity gains both from county public operating expenditures and 12^{th} grade passing scores. Reducing services in response to economic decline may not be a proper policy response as it raises a firm's production cost. A higher property tax coupled with higher public services contributes both to a friendly business climate and an improved quality of life.

Transportation and Trade: The only variable related directly to the NEG, distance to the nearest international airport, is significant though only weekly so. This supports the NEG model. However, in the context of Ohio, its impact is very small. This of course, does not mean that it would not be more important for traded good firms with greater forward and backward linkages to international markets. This can only be tested through a model that disaggregates the traded good sector accordingly. In addition, disaggregating industries according to their markets or the type of transport required (rail/sea, air) may also show the transport variable to be much more important.

Traditional LED Instruments − Human Resources: Traditional local economic development instruments are confirmed. One instrument emphasizes human resource development in the form of training and schooling. The results show that the traded good sector experiences a huge increase in productivity as a result of improved high school educational performance, an instrument very much influenced by local priorities and decision making. Also, educational attainment (percent of associate's degrees and higher) has the expected impact on income and productivity in the traded good sector. This variable is both the result of local support for schools and colleges, and the hiring policies of firms. Policy makers influence the former but not the latter. Still, educational attainment can be raised through incentive policies and local decisions that aim to attract firms with high skill and educational requirements.

Traditional LED Instruments − Infrastructure: Other traditional LED instruments include a focus on infrastructure. In our model infrastructure improvements in the form of road density and public water and sewerage networks improve the productivity of the housing sector but have no effect on the traded good sector or amenities. However, it indirectly raises quality of life via higher wages and lower housing prices that result from greater productivity. Infrastructure is widely recognized as a key variable of regional productivity in some of the literature (Andrews & Swanson, 1995; Eberts & McMillen, 1999; McCann & Shefer, 2004; Morrison & Schwartz, 1996; Munnell, 1990; Munnell, 1992). However, several recent articles contradict these findings (Crihfield & Panggabean, 1995; Haughwout, 1998; Haughwout, 2002; Holtz-Eakin, 1994; Holtz-Eakin & Schwartz, 1995). Our results can be seen as confirming both the first or second conclusion, depending on the sector. This means that traditional infrastructure investments such as roads are not currently as important as they may have been in the past. In the new economy, new types of infrastructure such as information networks, may be more important, but have not been modeled in this study.

Traditional LED Instruments − Support of Localization: Localization policies that aim to build a cluster of complementary activities also are shown to be significant in raising traded good sector productivity, though the magnitude of the effect is small. This impact would likely be larger in a model with a more disaggregated traded good sector, or with sample counties from a larger geographic area than Ohio.

Locational Advantages − Climate: The Florida/sunshine effect is well established in the literature, and it shows up highly significant and with great impact in our research. The average temperature in January is 26.0 degrees, with a maximum of 31.3 and a minimum of 22.0 degrees. There is little that policy makers can do about this, but it signals the great attraction of Florida to Ohio retirees. It is interesting that this variable is still as strong as it is within the modest temperature variations of Ohio. This information is important to policy makers both at the state and local level. While the facts cannot be changed, marketing and promotion can counter negatives and highlight the positives. At the state level, it can help the Department of Development to understand wider trends and react to them. The information could be used to promote the sunshine areas of the state. Alternatively, it can be used to increase awareness of what ails the formerly highly industrialized lakeside counties. It is not just deindustrialization, but it is also the sunshine effect, which makes it difficult to compete with other more southern Ohio locations. Of course, the region has partly compensating advantages from the Lake's leisure value. So depending on whether a firm looks for sunshine or leisure, the estimates provide some guidance as to where to locate, and the compensating wage variations associated with different locations in Ohio.

Locational Advantages − Coastal Amenities: The Great Lakes effect is similar potentially to the effect one might find in a geographic sample that includes coastal regions. However, while the Great Lakes Region has great amenity value for consumers, it has no effect on productivity, whereas for coastal locations, we would expect proximity to the coast (or to a port) to generate significant traded good economies. This will be interesting to consider in a follow-up paper. The lack of significance may be also related to manufacturing declines. The leisure values of Cleveland and adjacent counties should be highlighted in promotional campaigns as a major benefit.

NIMBY: Some of the more interesting conclusions result from the estimated neighborhood effects. Our findings go beyond the evidence already available in the literature that shows the presence of spatial autocorrelation.

The first finding is that strong neighborhood effects exist at the county level, suggesting that impacts spread over significant distances beyond those suggested by recent research at the level of the firm. This confirms that there is a need to look at multi-county metropolitan areas as an economic unit.

Second, while we are not able to test the significance of neighborhood effects for each agglomeration factor, they are significant in the form of three groups – transmitted via each of the three dependent variables: population, income and housing price. Prominent among each group are local policy instruments: These include the quality and cost of local services for all three groups; infrastructure investments in the case of housing; international airport distance in the case of the traded good; and human resource quality including educational attainment and age of labor force in the case of the traded good sector. As these variables are under local control or influence, decision makers impact neighboring county welfare and productivity. This potentially gives rise to a host of policy suggestions: the need for hearings that provide voice to affected counties, the need for revenue sharing; the need for debate on the benefits of metropolitan government, and more. In general, it pays to be close to counties with a high level of services, a good infrastructure, and a well educated labor force.

Third, a particularly interesting neighborhood effect is associated with population, as it has negative own-county effects, yet positive neighborhood effects. Residents dislike the higher density, congestion and pollution associated with a rise in own-county population, but they like the variety, lower prices, and opportunities associated with living close to populous neighbors. This asymmetry generates interesting policy results, particularly in metropolitan areas where suburban counties abut a large central county. While the model treats all counties as equal and does not distinguish between rural and urban counties, or central and suburban counties, the result suggests a basic tension between counties of unequal size. To the extent that a central county has many times the population of a neighboring suburban county, its net amenities (own county disamenities plus spillovers from its suburban neighbors) will be smaller than those enjoyed by suburban counties. This tension likely can be overcome only through enabling legislation at the state level, which enables counties in a metropolitan area to share some of the costs and benefits associated with the provision of services.

2.7 Concluding Remarks

This study disentangles agglomeration economies in several dimensions: impacted agents, impacting factors, and spatial dependence. This framework can be extended in a number of ways.

Impacted Agents: The study develops a spatial equilibrium framework with three agents, including two sectors. This has permitted us to disaggregate the amenity and productivity impacts of agglomeration factors. The framework can be extended so that the government could be made another agent, introducing assumptions about typical local government behavior. This will allow us to model some agglomeration factors through separate structural equations permitting to introduce feedback effects from the local economy to the factors.

Impacting Factors: The study puts agglomeration factors at the center of an analysis of agglomeration economies and diseconomies. This had the advantage of identifying possible policy variables and provides estimates of policy impacts on worker consumers' amenities and sector productivities. So far, agglomeration factors have been limited to positive factors, leaving negative factors to be estimated as a residual using population size. It may be possible to find proxies for congestion, pollution and other diseconomies. This would provide further disaggregation and better estimates of the residual impact of population.

Spatial Dependence: The study estimates neighborhood effects related to agglomeration economies based on the interpretation of spatial regression models suggested by LeSage and Pace (2008; 2009). The literature suggests that agglomeration economies do not extend over more than short distances. Instead, our paper shows what is intuitively obvious, that agglomeration economies extend beyond county boundaries. There are several extensions here. First, one would be able to identify and estimate neighborhood effects of individual factors, rather than the overall agglomeration effects for each agent as estimated by the current model. With a greater number of observations it should be possible to identify the significance of individual neighborhood effects. Second, it would be interesting to estimate the spatial decay of the effects of different agglomeration factors. As the evidence suggests, some have a much higher decay than others. Third, even more interesting might be an analysis of metropolitan areas including their rural hinterland. This should make it possible to identify neighborhood effects between a central city and suburban ring, or between the metropolitan area and its rural hinterland. Of particular interests would be possible asymmetries in the neighborhood effects between these three types of areas, as mentioned in Section 2.6.2.

Chapter 3: Industrial Restructuring and Abandonment of Legacy Capital

3.1 Introduction

Deindustrialization and industrial restructuring have deeply impacted cities in many developed countries. Resources become underutilized, idle or even abandoned, leading to secondary effects in the form of negative spillovers on neighboring areas and a spiral of further decline. Markets will try to clear by lowering capital prices though this may not work, as abandonment may coexists with a positive price for capital that seemingly, has no current use. Here we refer to capital that is immobile, non-malleable, and difficult or costly to reuse as legacy capital. What determines whether legacy capital is abandoned or converted to new uses? What determines the length of the abandonment period? Will abandoned capital always be re-used eventually?

While some scholars have modeled the abandonment of a building, particularly a housing structure, they have not dealt with industrial restructuring and the conversion of capital to new uses. Brueckner's (1980; 1981) housing life cycle model allows for the possibility of abandonment, though initially based on myopic price assumptions. The later model relaxes these assumptions, but abandonment becomes infinite and non-reversible, and different from many cases in reality, the price of abandoned housing becomes zero. O'Flaherty (1993) shows that the price of abandoned property can be positive if housing profits are uncertain. White (1986) models the role of property taxes in the abandonment of housing. All of these studies however, model residential property and housing life-cycle decisions made by an individual home owner. Instead, the framework proposed here models commercial and industrial property in the presence of an external shock. Different from life-cycle models, the investment cost is sunk, and owners are faced with a decision on how to dispose of a property in the face of declining life expectations for their firm. Decisions in this case depend on the interactions of three agents – firms in a declining sector here taken to be the manufacturing sector, firms in a stagnant or growing sector, here taken to be the commercial sector, and government and/or speculators willing to hold idle property – each optimizing their individual profit functions in the conversion and possible abandonment of urban legacy capital under conditions of perfect foresight.

We investigate how legacy properties are abandoned in the process of industrial restructuring, and how they are converted to a new use. When one industry declines and another rises, land uses must change as properties are transferred in line with the transition from one industry to another. While this transfer may be smooth in some cases, it may involve prolonged periods of abandonment in others. This paper proposes a theoretical model to identify the conditions for abandonment and the factors that determine the length of abandonment during the process of industrial restructuring.

The model is based on the investment and disinvestment behavior of urban firms and the taxation policies of local government. An outgoing firm faced with continuous decline in demand decides on its disinvestment schedule, while an incoming firm faced with stagnant or rising demand decides on its investment schedule. The local government levies a property tax on realty and alone or with speculator intermediation, holds abandoned property. All three actors interact to maximize own profits or proceeds. This interaction is modeled with a game theoretic framework in a certainty world of complete information.

This paper will show that the outcome of interactions depends on several parameters characterizing the economic environment: First, it depends on the cost of converting a property to new uses, such as remodeling and rebuilding costs. The greater these costs, the longer will market entry be delayed for a new commercial firm, and the longer will the property remain abandoned. Second, it depends on the rate of growth in the commercial sector and the rate of decline in the manufacturing sector. The abandonment period of the property will become longer, the lower is the rate of growth and the higher is the rate of decline. Third, policy variables also influence the outcome. The abandonment period of the property will become longer, the higher the tax rate, and the longer the maximum period of tax delinquency.

The paper also derives alternatives to the market equilibrium. The first alternative is the efficient time of capital use conversion to maximize the total output from legacy capital. The second one is an optimum to maximize a representative urban resident's welfare. That welfare depends on the length of time that an asset remains idle as well as on its use prior and following abandonment. Each of the optima is implemented by government through a suitable change in property tax rate, change in delinquency policies, or subsidy to conversion cost.

3.2 Settings

There are three representative players: A manufacturing firm, a commercial entrepreneur, and the local government. A building on a lot of fixed size has been used for manufacture, but this sector is now rapidly declining. The manufacturer is disinvesting capital other than real property and laying off labor to cope with the fall in the demand for its output. The commercial entrepreneur is seeking real property on which it can do business, faced with a demand that rises, though at a very low rate compared to the rate of manufacturing decline. The local government collects property taxes from the manufacturer. It allows the firm to be tax delinquent for some time but eventually seizes the property in line with given tax delinquency rules.

The current paper assumes that the city property market is closed. No property is available other than the property that will be released by the manufacturer, as all city land is being used by existing firms. An alternative is to assume that property is available at a floor price, and in this case, the commercial firm will make use of the property released by the industrial firm only if its price plus conversion costs are lower than the floor price for vacant land plus construction cost. This alternative version is richer in terms of behavioral options that can be explained, but will be discussed in a separate paper.

The three players try to maximize their own profits or proceeds. First, the declining manufacturer maximizes its operating profit and the benefit from non-payment of tax by choosing when it begins to default on property tax payments, thus indirectly determining the point when it forfeits the property to the local government. In the current model, the local government seizes property after a fixed given period of delinquency. The manufacturer therefore must choose the optimal onset of tax delinquency, given the maximum period of delinquency. Second, the commercial entrepreneur maximizes its profit by purchasing the property from the manufacturing firm or the local government and commencing business operations. It has to decide the optimal entry time, with the price of the property asked by the seller. Third, the local government maximizes the present value of cash flow from the forfeited property. It must choose the optimal asking price of the property, given the response of the buyer to its pricing.

The three players should interact with each other and each chooses their own course of action. During the period of tax delinquency, the manufacturer and the commercial entrepreneur participate in a trading game for the property. If the trade is not accomplished, then the property is forfeited to the local government, and a new trading game is played between the local government and the new buyer. Even in the second case, the property must sell at a positive price and be converted into commercial property at some point. Since this is sure to occur in the future, the abandoned property will have a positive price.

The environment is defined by the following parameters: Conversion costs, rates of growth and decline in the two sectors, and tax rate and grace period for property tax. First, conversion costs are costs used to convert the use of the property, including demolition cost and rebuilding cost. The amount of those costs is assumed to be increasing in the property size more than proportionately, that is, a convex function of the property size. Second, the rates of growth and decline in the two sectors are assumed to be constant over time. The rate of growth in the commercial sector is smaller than the interest rate, while the rate of decline in the manufacturing sector is greater than that. Third, municipal policies are characterized by tax rate and grace period. They are assumed to be predetermined and constant over time.

The outcomes of interactions among the three players are characterized by the selling time for the property (or the buyer's entry time) and its price. If the selling time is later than the forfeiture time, it means that the property is abandoned for some time. If not, it means that there is no idleness for the property. The price of the property in equilibrium is the price that the buyer is willing to pay and the seller accepts at the selling time.

3.3 (Dis) investment in Industrial and Commercial Sectors

3.3.1 Manufacturing Firm

3.3.1.1 Manufacturing Decline and Disinvestment

The monopolistic firm in the manufacturing sector produces output at time *t* using capital and labor on an indivisible industrial property of size $\hat{L}_0$. Since the real estate input is fixed during operation, we can drop it from the production set. Then the production function is written as

$$\hat{Q}_t = \hat{K}_t^a \hat{N}_t^{1-a}, 0 < a < 1$$

where $\hat{Q}_t$ is output, $\hat{K}_t$ is capital, and $\hat{N}_t$ is labor at time *t*. The wage rate of labor and the price of capital are exogenously given at *w* and *b*, respectively. The firm faces iso-elastic demand schedule,

$$\hat{Q}_t = X_t \hat{P}_t^{-\varepsilon}, \varepsilon > 1$$

where $\hat{P}_t$ is the output price and X_t is the coefficient of the demand function that is determined by the total income of consumers and the price index. Then one can show that the operating profit function is

$$\hat{\pi}\left(\hat{K}_t, X_t\right) = \frac{h}{1-\gamma} X_t^{\gamma} \hat{K}_t^{1-\gamma}$$

where, $h = (1-\gamma)(\varepsilon\gamma)^{-\varepsilon\gamma}(\varepsilon\gamma - 1)^{\varepsilon\gamma-1} w^{1-\varepsilon\gamma} > 0$, and $\gamma = 1/[1 + a(\varepsilon - 1)]$.

The market demand for the product is shrinking due to the low prices of other products that can substitute for it. For instance, as cheap substitutes are imported from abroad, the demand for the good is tapering off. Assume that the demand coefficient evolves according to

$$\frac{dX_t}{X_t} = -\mu_X dt \Rightarrow X_t = X_0 e^{-\mu_x t}, \mu_x > 0$$

where, X_0 is a constant, and μ_x is the rate of decline of the demand for the output. Then the operating profit function is written as

$$\hat{\pi}(\hat{K}_t;\, X_0) = \frac{h}{1-\gamma} X_0^{\gamma}\, e^{-\mu_x \gamma t} \hat{K}_t^{1-\gamma} \tag{3.1}$$

Faced with diminishing demand, the firm should disinvest capital by solving the following problem:

$$\max_{\{D_t\}_0^{t_f}} \int_0^{t_f} e^{-rt}\left[\hat{\pi}(\hat{K}_t, X_t) + bD_t\right] dt$$

$$\text{s.t.}\, \dot{\hat{K}}_t = -D_t - \delta t$$

$$X_0 \text{ is given}$$

where t_f is the time for shut down, D_t is disinvestment plan, b is the price of capital, r is the discount rate, and δ is the depreciation rate.

To solve this dynamic optimization problem, consider the Hamiltonian H_1.

$$H_1 = e^{-rt}\left[\hat{\pi}(\hat{K}_t, X_t) + (b - \lambda_t)D_t - \delta K_t\right]$$

Since it is linear in the control variable D_t, the following disinvestment rule is obviously optimal:

$$D_t \begin{cases} > 0, \text{if } b > \lambda_t \\ < 0, \text{if } b < \lambda_t \end{cases}$$

The optimal disinvestment instantaneously restores the marginal condition:

$$b = \lambda_t \tag{3.2}$$

That is, the price of capital should be always equalized to its shadow price. The canonical equation requires $d(e^{-rt}\lambda_t)/dt = -\partial H_1/\partial \hat{K}_t$, which is written as

$$\dot{\lambda}_t - (r+\delta)\lambda_t + \hat{\pi}_K(\hat{K}_t, X_t) = 0 \tag{3.3}$$

However, the shadow price of capital, λ_t is always constant as in (3.2), and hence (3.3) implies that the user cost of capital should equal the marginal operating profit as follows:

$$(r+\delta)\lambda_t = \hat{\pi}_K\left(\hat{K}_t, X_t\right)$$

Using (3.1), it is readily solved for the optimal path of capital,

$$\hat{K}_t = \hat{K}_0 e^{-\mu_x t} \text{ with } \hat{K}_0 = \left[\frac{h}{b(r+\delta)}\right]^{\frac{1}{\gamma}} X_0 \tag{3.4}$$

One can see that the capital should decrease at the same rate at which demand declines. To make the problem interesting, assume that this rate is larger than the depreciation rate, that is, $\mu_x > \delta$. Substituting this into the law of motion for capital and (3.1) yields

$$D_t^* = \begin{cases} \hat{K}_0\ (\mu_x - \delta) e^{-\mu_x t}, & \text{for } t > 0 \\ \hat{K}_0\ e^{-\mu_x t_f}, & \text{for } t = t_f \end{cases} \tag{3.5}$$

$$\hat{\pi}\left(t;\ \hat{K}_0\right) = b\hat{K}_0 \frac{(r+\delta)}{1-\gamma}\ e^{-\mu_x t} \tag{3.6}$$

3.3.1.2 Tax Delinquency and Forfeiture

The firm should pay fixed property tax τ. As usual, the local government allows tax delinquency for a period of d without seizing the property immediately. The declining firm chooses not to pay the tax from some point t_d onward and forfeits its property after the grace period.

The local government sets the grace period d according to a reasonable rule. As revenue maximizers, local governments would like to minimize the period of delinquency, i.e. set it equal to zero. Resistance from tax payers, however, and administrative costs and delays suggest a longer period. In the model, the grace period is assumed to be given exogenously.

Given the grace period d, the firm must choose the best starting point of tax delinquency, t_d. Let J_0 be the present value of future cash flows before tax payments from operating the firm. Formally,

$$J_0 = \max_{\{D_t\}_0^{t_f}} \int_0^{t_f} e^{-rt} \left[\hat{\pi}\left(\hat{K}_t, X_t\right) + bD_t\right] dt$$

$$s.t. \dot{\hat{K}}_t = -D_t - \delta \hat{K}_t$$

$$\hat{K}_0 = \left[\frac{h}{b(r+\delta)}\right]^{\frac{1}{\gamma}} X_0 \text{ is given}$$

Then the firm should solve the following problem:

$$\max_{t_d} J_0 - \int_0^{t_d} \tau e^{-rt} dt$$

Let the value including tax payments be $\hat{J}_0(t_d)$. Using the results (3.4), (3.5), and (3.6), the value function $\hat{J}_0(t_d)$ can be derived as follows:

$$\hat{J}_0(t_d) = b\hat{K}_0 \int_0^{t_f} e^{-(\mu_x + r)t} \left[\frac{r+\delta}{1-\gamma} + \mu_x - \delta\right] dt - \int_0^{t_d} \tau e^{-rt} dt$$
$$+ b\hat{K}_0 e^{-(\mu_x + r)t_f}$$

Taking the first derivative with respect to $t_d = t_f - d$ and equating it to zero yields the optimal onset of tax delinquency, t_d^*

$$t_d^* = \frac{1}{\mu_x} \log\left[\frac{(r+\delta)\gamma b\hat{K}_0}{\tau(1-\gamma)}\right] - \frac{\mu_x + r}{\mu_x} d \qquad (3.7)$$

This equation represents the firm's optimal strategy of tax delinquency, faced with a rule for the grace period. The tax payer, the manufacturing firm in this case, would like to maximize the present value of its cash flows by choosing the optimal starting point of the tax delinquency under the constraint that the property should be forfeited at the end of the grace period. Equation (3.7) shows the best strategy for the firm. One can see that one year increase in the grace period moves up the starting point of tax delinquency by more than one year.

During the grace period, the manufacturing firm has two options, sale or forfeiture. First, it can sell the property directly to the commercial entrepreneur before forfeiture, that is, at time $t_s < t_f$. The details will be discussed in Section 3.4.2.3. Second, if it fails to be sold, the property should be forfeited to the local government and then be abandoned until the commercial entrepreneur buys it at the price asked by the local government. The forfeiture time t_f is then mechanically determined by

$$t_f = t_d^* + d = \frac{1}{\mu_x}\log\left[\frac{(r+\delta)\gamma b\widehat{K}_0}{\tau(1-\gamma)}\right] - \frac{r}{\mu_x}d \tag{3.8}$$

This equation suggests that an increase in the grace period moves up the forfeiture time as well as the onset of tax delinquency. This is because a one year increase in the grace period moves up the starting point of tax delinquency by more than one year, as mentioned earlier.

Now consider the time when net profit of the firm is equal to the property tax. The operating profit is given by (3.6) and the user cost of capital is given as$(r+)b\widehat{K}_0 e^{-\mu_x t}$. Since net profit is computed as the subtraction of the latter from the former, it is

$$\phi_M = \frac{(r+\delta)\gamma b\widehat{K}_0}{1-\gamma} e^{-\mu_x t} \tag{3.9}$$

Hence the time when profit net of tax becomes zero is computed as

$$\tilde{t} = \frac{1}{\mu_x}\log\frac{(r+\delta)\gamma b\widehat{K}_0}{\tau(1-\gamma)} \tag{3.10}$$

One can see that this is identical to the first term of t_d^* and t_f. This fact allows us to rewrite t_d^* and t_f simply as

$$t_d^* = \tilde{t} - \left(1 + \frac{r}{\mu_x}\right)d \tag{3.11}$$

$$t_f = \tilde{t} - \frac{r}{\mu_x} d \tag{3.12}$$

Note that tax delinquency starts and ends prior to the time when the firm's profit net of tax is zero. In other words, the firm closes before its net cash flow (except from disinvestment) reaches zero. As the grace period is increased, the gap between plant closure and the time of zero net cash flow also increases. The intuition here is as follows: The firm would like to take advantage of tax delinquency as well as plant operations. If the interest rate is zero, the firm will close its plant exactly at $t = \tilde{t} - d$. A positive interest rate (time preference) advances this schedule by rd/μ_x.

3.3.2 Existing Commercial Firms

3.3.2.1 Commercial Production in Stationary equilibrium

Suppose that the commercial sector is composed of many small firms that employ the same technology of constant returns to scale. Since the output sells in a competitive market, all the firms are price takers. Hence the production in the commercial sector can be modeled with a representative firm, even though their sizes are not necessarily equal. The firm produces output at time *t* using capital, labor, and real property. The production function is

$$q_t = A_t K_t^{\alpha} N_t^{\beta} L_t^{1-\alpha-\beta}, 0 < \alpha, \beta < 1 \text{ and } 0 < \alpha + \beta < 1 \tag{3.13}$$

where A_t is total factor productivity (TFP), q_t is output, K_t is capital, N_t is labor, and L_t is realty. The wage rate of labor, the price of capital, and the price of realty are exogenously given at w, p_K, and $\bar{p}_L$, respectively. The demand schedule for the commercial good is also iso-elastic,

$$Q_t^D = Y_t P_t^{-\sigma}, \sigma > 1 \tag{3.14}$$

where σ is the price elasticity of demand, Q_t^D is the total quantity at market, and P_t is the output price and Y_t is the coefficient of the demand function that is impacted by the total income of consumers and the prices of substitutes for the good.

Suppose that the market is initially in stationary equilibrium with price P_0. Since factor employment is optimized, the marginal revenue product of the representative firm must be equalized to the marginal cost in equilibrium as follows:

$$c = (r + \rho)p_K = \frac{\alpha}{K_0} P_0 q_0 \tag{3.15}$$

$$w = \frac{\beta}{N_0} P_0 q_0 \tag{3.16}$$

$$l = r\bar{p}_L = \frac{1 - \alpha - \beta}{L_0} P_0 q_0 \tag{3.17}$$

where c and l are user costs of capital and realty, respectively, ρ is the depreciation rate of capital, and K_0, N_0, and L_0 are stationary sate of the three factors. (3.15), (3.16), and (3.17) imply the following factor ratios

$$K_0 = \frac{\alpha l}{(1 - \alpha - \beta)c} L_0$$

$$N_0 = \frac{\beta l}{(1 - \alpha - \beta)w} L_0$$

Substituting these expressions into (3.13) yields the equilibrium realty input as a function of the total output

$$L_0 = \frac{q_0}{A_0}\left(\frac{1 - \alpha - \beta}{l}\right)^{\alpha+\beta} \left(\frac{c}{\alpha}\right)^{\alpha} \left(\frac{w}{\beta}\right)^{\beta} \tag{3.18}$$

Using (3.15), (3.16), and (3.17), one can compute the total cost $C(q_0) = cK_0 + wN_0 + lL_0$ as a function of total output in equilibrium as follows:

$$C(q_0) = \frac{q_0}{A_0}\left(\frac{l}{1 - \alpha - \beta}\right)^{1-\alpha-\beta} \left(\frac{c}{\alpha}\right)^{\alpha} \left(\frac{w}{\beta}\right)^{\beta}$$

Substituting $r\bar{p}_L$ for l and taking the derivative with respect to q_0 yields the following marginal cost function:

$$C^{'}(q_0) = \frac{1}{A_0}\left(\frac{r\bar{p}_L}{1-\alpha-\beta}\right)^{1-\alpha-\beta}\left(\frac{c}{\alpha}\right)^{\alpha}\left(\frac{w}{\beta}\right)^{\beta} = P_0 \tag{3.19}$$

The second equality should hold as the firm sells its output in a competitive market. This equation suggests the relationship between the output price and the realty price.

3.3.2.2 Growth of Demand and Price Change

Now suppose that the demand for the output rises over time. Formally, Y_t develops according to the following trend:

$$\frac{dY_t}{Y_t} = \mu_y dt \Rightarrow Y_t = Y_0 e^{\mu_y t}, 0 \leq \mu_y < \mu_x$$

where Y_0 is a constant, and μ_y is the rate of growth of the demand for the output. Using (3.14) and (3.19), the equilibrium condition at time 0 can be written as

$$\frac{Y_0}{Q_0} = P_0^{\sigma} = \left[\frac{1}{A_0}\left(\frac{l}{1-\alpha-\beta}\right)^{1-\alpha-\beta}\left(\frac{c}{\alpha}\right)^{\alpha}\left(\frac{w}{\beta}\right)^{\beta}\right]^{\sigma}$$

Faced with rising demand, the firm should invest more to maximize its profit. It must employ more inputs to produce more. However, no real property is available for now as all urban land is being used. Given the current amount of realty L_0, it must choose the optimal level of the other inputs dynamically. At time *t*, the firm first should pick the optimal input of labor given the level of capital K_t and realty L_0 by solving

$$\max_{N_t} P_t q_t - wN_t$$

$$s.t. q_t = A_t K_t^{\alpha} N_t^{\beta} L_0^{1-\alpha-\beta}$$

where P_t is the output price at time *t* that is determined in the competitive market. The optimal level of labor at time *t* is given by

$$N_t = \left[\frac{A_t \beta K_t^{\alpha} L_0^{1-\alpha-\beta}}{w} P_t\right]^{\frac{1}{1-\beta}} \tag{3.20}$$

Substituting (3.20) into the objective function yields the operating profit at time *t*

$$\pi(K_t, P_t) = (1-\beta)\left[A_t \boldsymbol{L}_0^{1-\alpha-\beta} \left(\frac{\beta}{w}\right)^{\beta} K_t^{\alpha} P_t\right]^{\frac{1}{1-\beta}} \tag{3.21}$$

Given this operating profit, the firm should choose the optimal investment plan by solving

$$\max_{\{I_t\}_0^{\infty}} \int_0^{\infty} e^{-rt} [\pi(K_t, P_t) - p_k I_t] dt$$

$$s.t. \dot{K}_t = \mathrm{I}_t - \rho K_t$$

$$P_t \text{ is given}$$

where I_t is the investment plan and ρ is the depreciation rate of capital. One can solve this problem in the same way as for the manufacturing firm's disinvestment problem using optimal control theory. The user cost of capital should be equal to the marginal operating profit as follows:

$$(r+\rho)p_K = c = \pi_K(K_t, P_t) \tag{3.22}$$

Substituting (3.21) into (3.22) and solving for K_t yields

$$K_t = \left[A_t \left(\frac{\alpha}{c}\right)^{1-\beta} \left(\frac{\beta}{w}\right)^{\beta} P_t\right]^{\frac{1}{1-\alpha-\beta}} L_0 \tag{3.23}$$

$$N_t = \left[A_t \left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{1-\alpha} P_t\right]^{\frac{1}{1-\alpha-\beta}} L_0$$

The supply by the commercial firm at time t is obtained by substituting (3.23) and (3.20) into the production function (3.13) as follows:

$$q_t = \left[A_t \left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{\beta} P_t^{\alpha+\beta}\right]^{\frac{1}{1-\alpha-\beta}} L_0 \tag{3.24}$$

The level of realty L_0 is determined in the previous stationary equilibrium as shown in (3.18), and thus (3.24) is rewritten as

$$q_t = \frac{q_0}{A_0}\ A_t^{\frac{1}{1-\alpha-\beta}} \left[\left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{\beta} P_t\right]^{\frac{\alpha+\beta}{1-\alpha-\beta}} \left(\frac{1-\alpha-\beta}{l}\right)^{\alpha+\beta} \tag{3.25}$$

Every firm in the commercial sector behaves in the same way as above, and thus one can impose symmetry to (3.25). Summing over all firms yields the supply schedule in the commercial good market as:

$$Q_t^S = \frac{\mathrm{Q}_0}{A_0}\ A_t^{\frac{1}{1-\alpha-\beta}} \left[\left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{\beta} P_t\right]^{\frac{\alpha+\beta}{1-\alpha-\beta}} \left(\frac{1-\alpha-\beta}{l}\right)^{\alpha+\beta} \tag{3.26}$$

where Q_t^S is the total market supply at time t and Q_0 is the total output in stationary equilibrium at time 0. Note that the total factor productivity (TFP) at time t, A_t is distinguished from the initial one A_0, because TFP is assumed to be influenced by the environment.

Using the supply and demand schedules in (3.14) and (3.26), the output price in equilibrium is computed as

$$P_t = \left(\frac{c}{\alpha}\right)^{\alpha} \left(\frac{w}{\beta}\right)^{\beta} \left(\frac{l}{\mathrm{v}}\right)^{\mathrm{v}} \left[A_t A_0^{(\sigma-1)\mathrm{v}}\right]^{\frac{-1}{\alpha+\beta+\sigma\nu}} e^{\mu t} \tag{3.27}$$

where $\nu = 1-\alpha-\beta$ and $\mu = \frac{\nu}{\alpha+\beta+\sigma\nu}\mu_y$. Notable is that the out price grows at the rate of μ, which is much smaller than the growth rate of demand, μ_y. As expected, the growth rate of output price is increasing in the share of realty cost $\nu = 1 - \alpha - \beta$ and decreasing in the elasticity of substitution σ.

3.4 Conversion of Legacy Property

3.4.1 Investment on Legacy Property

Now consider the real property released by the manufacturing firm. Suppose that its size $\hat{L}_0$ is small relative to the total size of commercial properties, so its addition does not impact the price of commercial properties. The commercial entrepreneur will consider purchasing this property, given the rising demand for commercial services and given the asking price of the property plus the cost of converting it to its new use. Specifically, the commercial entrepreneur chooses an optimal investment plan to maximize the present value of its future cash flows.

Let $\tilde{p}_L$ denote the asking price of the property, and $S(\hat{L}_0)$ be the cost of converting and adjusting the property, in short, conversion cost. The function of conversion cost is an increasing convex function[15] of property size $\hat{L}_0$ that satisfies the following conditions:

$$S(0) = 0,\ S^{'}(\cdot) > 0,\ S^{''}(\cdot) > 0 \tag{3.28}$$

The firm must choose the optimal investment plan for its planning horizon to cope with the growth in demand for its output to:

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[15] This assumption is not critical but only for the illustration purpose, and hence one may assume that the function is concave or even linear in property size. But convex adjustment cost functions are often used in investment theory (Gould, 1968; Lucas Jr., 1967; Treadway, 1969). The rationale is as follows: The larger the size of new investment, the more changes in the existing organization is needed. As a result, there are decreasing returns to scale in adjustment.

$$\max_{\{I_t\}_{t_e}^{T}} \int_{t_e}^{T} e^{-rt} \left[\tilde{\pi}\left(\tilde{K}_t, P_t\right) - p_K \tilde{I}_t\right] dt - \left(\tilde{p}_L \hat{L}_0 + S\right) e^{-rt_e} + \bar{\bar{p}}_L \hat{L}_0 e^{-rT}$$

$$s.t. \dot{\tilde{K}}_t = \tilde{I}_t - \rho \tilde{K}_t \tag{3.29}$$

$$\tilde{K}_t = 0 \text{ for } 0 \leq t < t_e$$

$$P_t \text{ is given}$$

where t_e is the time of market entry, T is the time for the firm's closure or investment horizon, $\tilde{I}_t$ is the investment at time t, and $\bar{\bar{p}}_L$ is the resale price of the realty at the time of closure. Since the impact on the output market of the operation of the new firm is negligible, the output price P_t is given by (3.27). The problem can be solved in the same manner as in the representative commercial firm's investment problem. The following results are analogous to (3.23) and (3.20).

$$\tilde{K}_t = \left[A_t \left(\frac{\alpha}{c}\right)^{1-\beta} \left(\frac{\beta}{w}\right)^{\beta} P_t\right]^{\frac{1}{\nu}} \hat{L}_0 \tag{3.30}$$

$$\tilde{N}_t = \left[A_t \left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{1-\alpha} P_t\right]^{\frac{1}{\nu}} \hat{L}_0 \tag{3.31}$$

Substituting (3.30) into (3.21) yield the operating profit as

$$\tilde{\pi}\left(\tilde{K}_t, P_t; \hat{L}_0\right) = (1-\beta) \left[A_t \left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{\beta} P_t\right]^{\frac{1}{\nu}} \hat{L}_0 \tag{3.32}$$

We also obtain the following expressions by substituting (3.27) for P_t in (3.30), (3.31) and (3.32):

$$\tilde{K}_t = \frac{\alpha l}{\nu c} \left(\frac{A_t}{A_0}\right)^{\epsilon} \hat{L}_0 e^{\mu t} \tag{3.33}$$

$$\tilde{N}_t = \frac{\beta l}{\nu w} \left(\frac{A_t}{A_0}\right)^{\epsilon} \hat{L}_0 e^{\mu t}$$

$$\tilde{\pi}(t;\hat{L}_0) = \frac{(1-\beta)l}{\nu}\left(\frac{A_t}{A_0}\right)^{\epsilon}\hat{L}_0 e^{\mu t} \tag{3.34}$$

where $\epsilon = (\sigma - 1)/(\alpha + \beta + \sigma\nu)$ and $\mu = \mu_y/[\alpha + \beta + \sigma(1 - \alpha - \beta)] < \mu_y$ are constants.[16] The law of motion for capital implies $\tilde{I}_t = (\mu + \rho)\tilde{K}_t$ and thus the optimal investment plan is

$$\tilde{I}_t^* = \begin{cases} \tilde{K}_{t_e} = \dfrac{\alpha l}{(1-\alpha-\beta)c}\left(\dfrac{A_{t_e}}{A_0}\right)^{\epsilon}\hat{L}_0 e^{\mu t_e} & \text{for } t = t_e \\ (\mu+\rho)\tilde{K}_{t_e} = \dfrac{\alpha(\mu+\rho)l}{(1-\alpha-\beta)c}\left(\dfrac{A_t}{A_0}\right)^{\epsilon}\hat{L}_0 e^{\mu t} & \text{for } t_e < t < T \\ -\tilde{K}_T = -\dfrac{\alpha l}{(1-\alpha-\beta)c}\left(\dfrac{A_T}{A_0}\right)^{\epsilon}\hat{L}_0 e^{\mu T} & \text{for } t = T \end{cases} \tag{3.35}$$

The rates of growth of capital, labor, and operating profit are all μ. This value is obviously smaller than the rate of decline of the manufacturing firm, that is, $\mu < \mu_x$, because $\mu_y < \mu_x$ by assumption and $\mu < \mu_y$ as mentioned earlier.

The entrepreneur must choose the optimal entry time as well as the optimal investment plan. The operating profit grows very slowly and the initial entry costs are high. Therefore, too early an entry may result in negative profits until demand is high enough to cover the interest of the entry costs, and too late an entry may waste potential profits. The choice of entry time will among others depend on the asking price of the property. This interaction between the incoming commercial firm on the one hand, and the outgoing manufacturing firm or the local government holding the property on the other hand, should be modeled within the framework of a trading game, see the following section.

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[16] One can see that ϵ approaches to zero and μ does μ_y as σ approaches unity.

3.4.2 Trading Game for Legacy Property

The selling price and time for the legacy property are determined by the interaction between the seller and the buyer. The bilateral trade is modeled as a game where the seller asks a selling price and the buyer responds by offering a sale time. It can be also be modeled as a game where the two players play the opposite roles or each of them offers a schedule of prices, each at a particular time, to reach equilibrium. In any cases, the seller would like to sell the property at a high price as soon as possible, while the buyer wants to buy it at a low price at an appropriate time. Since this nature of the game does not change, the outcomes will be the same regardless of the ways the trade is modeled.

In this bilateral trade game, while the buyer is always only the commercial entrepreneur, the seller is either the local government or the manufacturing firm depending on whether the sale is accomplished after or before forfeiture. Let's look at each of these cases in turn.

3.4.2.1 Commercial Entrepreneur's Choice of Entry Time

Given the price of the property, the entrepreneur in the commercial sector chooses its entry time to maximize the present value of future cash flows. Let $V_0(t_e)$ denote the value function at time 0 of the firm entering at time t_e, that is, the value function of the problem (36). Then the buyer maximizes the value by solving the problem:

$$\max_{t_e} V_0(t_e)$$
$$s.t.\ \ \tilde{p}_L \text{ is given}$$

The value function is obtained by substituting (3.33), (3.34), and (3.35) into the objective functional of the dynamic program (3.29). However, since A_t is influenced by the environment and changes over time, it is impossible to obtain a closed form of the value function for a general case. For simplicity, now assume that the environment and TFP do not change over time. Then the productivity becomes constant, that is, $A_t = A_0$, and thus we can get a closed form as follows:

$$V_0(t_e; \tilde{p}_L) = \frac{r\bar{p}_L\hat{L}_0}{\mu - r}\left[e^{(\mu-r)T} - e^{(\mu-r)t_e}\right] + \bar{\bar{p}}_L\hat{L}_0 e^{-rT} - \left(\tilde{p}_L\hat{L}_0 + S\right)e^{-rt_e} \quad (3.36)$$

If the horizon is infinite, the value becomes infinite unless the profit growth rate is smaller than the discount rate, that is, $\mu < r$. As shown earlier, the rate of profit growth is smaller than the rate of growth of commercial demand, $\mu < \mu_y$, but also μ_y is small by assumption. So $\mu < r$ is plausible. To solve the problem, take the first derivative of (3.36) with respect to t_e and equate it to zero. Then the optimal entry time is

$$t_e^*(\tilde{p}_L) = \frac{1}{\mu}\log\frac{\tilde{p}_L\hat{L}_0 + S}{\bar{p}_L\hat{L}_0} \quad (3.37)$$

This is the best response function of the buyer when the price of the property $\tilde{p}_L$ is asked by the seller. Alternatively, her strategy can be expressed as a set of bundles of price $\tilde{p}_{L,C}^*$ and entry time $t_{e,C}^*$ by rearranging (3.37) as follows:

$$\left\{\left(t_{e,C}^*, \tilde{p}_{L,C}^*\right)\right\} = \left\{(t_e, \tilde{p}_L) \mid \tilde{p}_L = \bar{p}_L e^{\mu t_e} - \frac{S}{\hat{L}_0}\right\} \quad (3.38)$$

The buyer's strategy (3.37) implies that as expected, the optimal entry time becomes delayed with higher price of the newly converted property, $\tilde{p}_L$.

$$\frac{\partial t_{e,C}^*}{\partial \tilde{p}_L} > 0$$

Equivalently, from (3.38), one can say that the buyer's offer price is increasing in its entry time.

$$\frac{\partial \tilde{p}_{L,C}^*}{\partial t_e} > 0 \quad (3.39)$$

With the optimal entry time for a given property price, the buyer can achieve the following value from operating a commercial firm:

$$V_0^* = -\frac{l\hat{L}_0}{r-\mu}e^{-(r-\mu)T} + \bar{\bar{p}}_L\hat{L}_0 e^{-rT} + \frac{\mu\bar{p}_L\hat{L}_0}{r-\mu}e^{-(r-\mu)t_e^*} \tag{3.40}$$

Substituting (3.37) into (3.40) yields the value per unit size of property in an infinite horizon as follows:

$$\lim_{T\to\infty}\frac{V_0}{\hat{L}_0} = \frac{\mu(\bar{p}_L)^{\frac{r}{\mu}}}{r-\mu}\left(\frac{\hat{L}_0}{\tilde{p}_L\hat{L}_0 + S}\right)^{\frac{r}{\mu}-1} > 0$$

One can see that the value function is decreasing in the price of the new property $\tilde{p}_L$ while it is increasing in the stationary price of existing properties, $\bar{p}_L$. Notable is that the firm can achieve a positive value in an infinite horizon no matter how high the price of the property, $\tilde{p}_L$ is.

3.4.2.2 Local Government's Asking Price

Now turn to the seller's strategy. First, consider the case where the local government is the seller of the property. If the manufacturing firm fails to pay property tax, then the property is forfeited to the local government, which behaves as an asset manager to maximize the present value of proceeds from the sale of the forfeited property.

Let t_f be the forfeiture time. Assume that the local government has complete information about the strategy of the buyer. Given the buyer's optimal strategy, the local government must choose the optimal price in the trade by solving the following problem:[17]

[17] The local government may levy property tax on the property after it is sold to a new buyer. Then the objective function must be $\left(\tilde{p}_L + \frac{\tau'}{r\hat{L}_0}\right)e^{-r(t_e^*-t_f)}$, where τ' is the new property tax. At the same time, the tax must influence the behavior of the buyer as well. The value function in (3.36) has to include the tax term, $-\frac{\tau}{r}e^{-rt_e}$. It is not difficult to show that the two effects of property tax offset each other in

$$\max_{\tilde{p}_L} \tilde{p}_L e^{-r(t_e^* - t_f)}$$

$$s.t.\ t_e^*(\tilde{p}_L) \geq t_f$$

where $t_e^*(\tilde{p}_L)$ is determined by the optimal strategy of the buyer as shown in (3.38). The constraint requires that the property is seized before it is sold. Since t_e^* is a monotonically increasing function of $\tilde{p}_L$ as in (47), the constraint is equivalently written as

$$\tilde{p}_L \geq t_e^{*-1}(t_f)$$

The maximand has only one global maximum, but the constraint makes the solution vary depending on whether the constraint is binding or not. The first order condition suggests the local government's solution be

$$\tilde{p}_{L,G}^* = \begin{cases} \frac{1}{r}\left(\frac{\partial t_e^*}{\partial \tilde{p}_L}\right)^{-1} & \text{if } t_e^*(\tilde{p}_L^*) > t_f \\ t_e^{*-1}(t_f) & \text{otherwise} \end{cases} \tag{3.41}$$

The first solution is for the case where the constraint is not binding, that is, the sale takes place when the local government has the right to the property. The second one is for the case where the constraint is binding, that is, the sale takes place as soon as the local government has the right to the property. Call the first one the unconstrained strategy and the second one the constrained strategy. With these response functions, the local government achieves the maximum present value of proceeds from selling the property.

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determining the equilibrium for the abandoned case. For simplicity, we omit the tax on the new use of the legacy property here.

3.4.2.3 Manufacturing Firm's Strategy

Second, consider the case where the seller (original owner) directly sells its property to the buyer at time t_s prior to the time of forfeiture t_f. This can occur as long as the buyer is willing to pay as high a price as the sum of the unpaid tax plus interest[18] and the discounted value of all future cash flows except the proceeds from disinvesting the remaining capital. Let $\tilde{p}_{L,M}$ denote the seller's property asking price at time t_s, then it must satisfy

$$\tilde{p}_{L,M}\hat{L}_0 \geq \int_{t_d^*}^{t_s} \tau e^{r(t_s - t)} dt + J_{t_s} - b\hat{K}_{t_s}$$

where J_{t_s} is the present value at time t_s of the future cash flows except tax payments from operating the manufacturing firm, that is,

$$J_{t_s} = b\hat{K}_0 \int_{t_s}^{t_f} e^{-r(t-t_s)} \left[\frac{r+\delta}{1-\gamma} + \mu_x - \delta\right] e^{-\mu_x t} dt + b\hat{K}_{t_f} e^{-r(t_f - t_s)}$$

Substituting J_{t_s} yields the following (asking) price frontier:

$$\begin{aligned} &\left(t_{e,M}^*, \tilde{p}_{L,M}^*\right) = \\ &\left\{(t_s, \tilde{p}_L) \mid \tilde{p}_L = \frac{\tau}{r\hat{L}_0}\left[e^{r(t_s - t_d^*)} - 1\right] \right. \\ &\qquad \left. + \frac{\gamma(r+\delta)b\hat{K}_0 e^{rt_s}}{(1-\gamma)(\mu_x + r)\hat{L}_0}\left[e^{-(\mu_x + r)t_s} - e^{-(\mu_x+r)t_f}\right]\right\} \\ &\qquad\qquad \text{with } t_s \in [t_d, t_f] \end{aligned} \tag{3.42}$$

The seller's asking price is monotonically decreasing in the time of sale, within the range of interest $D = [t_d, t_f]$, and its first derivative with respect to t_s is zero at $t_s = t_f$. Formally,

[18] Usually, some penalties are imposed for tax delinquency in reality. For simplicity, however, they are omitted in the model.

$$\frac{\partial \tilde{p}_{L,s}}{\partial t_s}\begin{cases} < 0 \; for \; t_s \in [t_d,\, t_f) \\ = 0 \text{ for } t_s = \; t_f \end{cases} \tag{3.43}$$

The intuition behind this is that the seller's declining asking price is related to the tax delinquency. As shown in (3.11) and (3.12), during the tax delinquency net profits exceed taxes due. But the seller's asking price will consist of unpaid tax and interest plus future net profits. As net the profit is higher than the tax, the asking price declines as the shut-down approaches with a minimum at t_f when future net profit is zero.

The direct trade between the seller (manufacturing firm) and the buyer (commercial entrepreneur) can be attained if and only if the buyer is able to accept a bundle of price and entry time that the seller offers according to (3.42). The buyer will decide whether to accept the asking price based on her own offer curve that is summarized in (3.38). In short, the two players' offer curves should intersect during the tax delinquency period $D = [t_d,\, t_f]$.

3.4.3 Equilibrium

3.4.3.1 Equilibrium in Sale by Local Government

In the trade between the commercial firm and the local government, the two players follow the best response strategies suggested by (3.37) and (3.41), respectively. Rewrite the two strategies:

Buyer: $t_e^*(\tilde{p}_L) = \frac{1}{\mu}\log\frac{\tilde{p}_L\hat{L}_0+S}{\bar{p}_L\hat{L}_0}$

Seller: $\tilde{p}_{L,G}^* = \begin{cases} \frac{1}{r}\left(\frac{\partial t_e^*}{\partial \tilde{p}_L}\right)^{-1} & \text{if } t_e^*(\tilde{p}_L^*) > t_f \text{ (Unconstrained strategy)} \\ t_e^{*-1}(t_f) & \text{otherwise} \qquad \text{(Constrained strategy)} \end{cases}$

Assume that both players know the other side's strategy. Then, if a bundle of price and entry time is to be a Nash Equilibrium, it must satisfy the two players' price offers at the same time. Since the local government has different strategies for two different cases, the equilibria should be determined for both cases.

Consider the case when the constraint is not binding. A Nash Equilibrium (NE) is obtained by solving the buyer's offer and the seller's unconstrained offer simultaneously. Let $\left(t_{e,2}^{*}, \tilde{p}_{L,2}^{*}\right)$ denote a NE in the sale by the local government. Then the solutions are

$$t_{e,2}^{*} = \frac{1}{\mu}\log\frac{rS}{\bar{p}_L \hat{L}_0 (r-\mu)} \tag{3.44}$$

$$\tilde{p}_{L,2}^{*} = \frac{\mu S}{(r-\mu)\hat{L}_0} \tag{3.45}$$

Using this solution, (3.37) and (3.41), the local government's strategy can be expressed as an explicit set of bundles of price $\tilde{p}_{L,G}^{*}$ and entry time $t_{e,G}^{*}$ as follows:

$$\left\{\left(t_{e,G}^{*}, \tilde{p}_{L,G}^{*}\right)\right\}$$
$$= \begin{cases} \left\{ (t_e, \tilde{p}_L) \;\middle|\; \tilde{p}_L = \dfrac{\mu (\bar{p}_L)^{\frac{r}{\mu}}}{r} \left[\dfrac{\hat{L}_0 (r-\mu)}{rS}\right]^{\frac{r}{\mu}-1} e^{r t_e} \right\} & \text{if } t_e^{*}(\tilde{p}_L^{*}) > t_f \\ \left\{ \left(t_f, \bar{p}_L e^{\mu t_f} - \dfrac{S}{\hat{L}_0} \right) \right\} & \text{otherwise} \end{cases} \tag{3.46}$$

Obviously, in the first case, the local government's asking price rises with the selling time, while it collapses into a point in the second case. The local government is interested in the present value of the property price and hence, in the first case, the offer price rises with at the interest rate. In the second case, however, it gets the highest present value only if it sells the property at the moment of forfeiture. It can realize this plan by offering the price that the buyer can accept at the forfeiture time. That is why its offer bundle is only one point in the second case.

For (3.44) and (3.45) to be a real equilibrium, the constraint $t_{e,2}^{*}\left(\tilde{p}_{L,2}^{*}\right) > t_f$ has to be met indeed. Using (3.8) and (3.45), this can be rewritten as

$$\frac{1}{\mu}\log\frac{rS}{\bar{p}_L\hat{L}_0(r-\mu)} > \frac{1}{\mu_x}\log\left[\frac{(r+\delta)\gamma b\hat{K}_0}{\tau(1-\gamma)}\right] - \frac{r}{\mu_x}d, \text{or}$$

$$\frac{rS}{\bar{p}_L\hat{L}_0(r-\mu)} > \left[\frac{(r+\delta)\gamma b\hat{K}_0}{\tau(1-\gamma)e^{rd}}\right]^{\frac{\mu}{\mu_x}} \tag{3.47}$$

If this condition is met, the solution (3.44) and (3.45) constitute a NE for the trading game for the legacy property between the local government and the commercial entrepreneur.

If the condition (3.47) is not met, that is, if

$$\frac{1}{\mu}\log\frac{rS}{\bar{p}_L\hat{L}_0(r-\mu)} \le \frac{1}{\mu_x}\log\left[\frac{(r+\delta)\gamma b\hat{K}_0}{\tau(1-\gamma)}\right] - \frac{r}{\mu_x}d, \text{or}$$

$$\frac{rS}{\bar{p}_L\hat{L}_0(r-\mu)} \le \left[\frac{(r+\delta)\gamma b\hat{K}_0}{\tau(1-\gamma)e^{rd}}\right]^{\frac{\mu}{\mu_x}} \tag{3.48}$$

then the constraint must be binding. So a NE is obtained by solving the buyer's offer and the seller's constrained offer simultaneously. The results are

$$t_{e,2}^* = t_f = \frac{1}{\mu_x}\log\left[\frac{(r+\delta)\gamma b\hat{K}_0}{\tau(1-\gamma)}\right] - \frac{r}{\mu_x}d \tag{3.49}$$

$$\tilde{p}_{L,2}^* = \bar{p}_L e^{\mu t_f} - \frac{S}{\hat{L}_0} = \bar{p}_L\left[\frac{(r+\delta)\gamma b\hat{K}_0}{\tau(1-\gamma)e^{rd}}\right]^{\frac{\mu}{\mu_x}} - \frac{S}{\hat{L}_0} \tag{3.50}$$

If condition (3.47) fails to be met, then the local government may as well sell the property at the very moment of seizing it, at whatever price the buyer can afford to pay. This case may not occur if the property is sold directly by the manufacturing firm. In other words, condition (3.48) assures that the property is sold either by the local government or by its original owner without being abandoned. The likelihood of this condition to be met is the greater, the higher the growth rate of the commercial sector, μ, the greater remaining capital, $b\hat{K}_0$, and the higher the stationary price of existing commercial properties, $\bar{p}_L$. It is also more likely the lower the rate of decline of the industrial sector, μ_x, the lower the property tax rate, and the lower conversion costs, S.

3.4.3.2 Equilibrium in Sale by Manufacturing Firm

In the trade between the commercial firm and the manufacturing firm, the two players follow the best response strategies suggested by (3.38) and (3.42), respectively. Rewrite the two strategies:

Buyer: $\left\{\left(t_{e,C}^{*}, \tilde{p}_{L,C}^{*}\right)\right\} = \left\{(t_e, \tilde{p}_L) \mid \tilde{p}_L = \bar{p}_L e^{\mu t_e} - \frac{S}{\hat{L}_0}\right\}$

Seller: $\left\{\left(t_{e,M}^{*}, \tilde{p}_{L,M}^{*}\right)\right\} =$

$$\left\{(t_s, \tilde{p}_L) \mid \ \tilde{p}_L \frac{\tau}{r\hat{L}_0}\left[e^{r\left(t_s - t_d^{*}\right)} - 1\right] + \frac{\gamma(r+\delta)b\hat{K}_0 e^{rt_s}}{(1-\gamma)(\mu_x + r)\hat{L}_0}\left[e^{-(\mu_x + r)t_s} - e^{-(\mu_x + r)t_f}\right]\right\}$$

A direct trade between the two players will take place if the above two offer curves intersect in the range $D = [t_d^{*},\ t_f]$. While the buyer's offer curve is monotonically increasing in entry time, the seller's offer curve monotonically decreases within the range of interest *D*.

For this case, one needs to look only at one time point t_f in order to check whether the two offer curves intersect within the range *D*. It is because the seller's offer curve is going down while the buyer's offer curve is going up in that range. If the buyer's offer price is not as high as the seller's at time t_f, then its means that the former is always lower than the latter and thus a direct trade will not occur at all. In other words, the following condition should be met for a direct trade to take place between the original owner and the newly coming firm before forfeiture:

$$\tilde{p}_{L,M}^{*}\left(t_f\right) \leq \tilde{p}_{L,C}^{*}\left(t_f\right)$$

Specifically, it can be rewritten as

$$\frac{\tau}{r\hat{L}_0}\left(e^{rd} - 1\right) \leq \bar{p}_L e^{\mu t_f} - \frac{S}{\hat{L}_0}, \text{ or}$$

$$S \leq \bar{p}_L \hat{L}_0 e^{\mu t_f} - \frac{\tau}{r}\left(e^{rd} - 1\right) \tag{3.51}$$

When the above condition is met, a direct trade is achieved between the manufacturing firm and the commercial entrepreneur. The selling price and time are determined by the condition that the two offer prices be the same, that is, $\tilde{p}^*_{L,M}(t_s) = \tilde{p}^*_{L,C}(t_s)$, though it is not easy to figure out the analytic solution.

Conversely, if the above condition is not met, formally,

$$\frac{\tau}{r\hat{L}_0}\left(e^{rd} - 1\right) > \bar{p}_L e^{\mu t_f} - \frac{S}{\hat{L}_0}, \text{or} \qquad (3.52)$$

$$S > \bar{p}_L \hat{L}_0 e^{\mu t_f} - \frac{\tau}{r}\left(e^{rd} - 1\right)$$

then the property may or may not be traded directly. A direct trade will occur at time t_f if the value of market entry with price $\tilde{p}^*_{L,M}\left(t_f\right)$ at t_f is higher than the value of market entry with price $\tilde{p}^*_{L,2}$ at $t^*_{e,2}$. This is so because commercial market entry at that time is more profitable than at time $t^*_{e,2}$. If this condition does not hold, then the property must be forfeited to the local government. Formally, if the following condition holds

$$V_0\left(t^*_{e,2}, \tilde{p}^*_{L,2}\right) > V_0\left(t_f, \tilde{p}^*_{L,M}(t_f)\right) \qquad (3.53)$$

then the direct trade will not occur and the property must be abandoned. In an infinite horizon, the value of the firm entering at t with the property price $\tilde{p}_L$ is given by (3.36) as

$$V_0(t, \tilde{p}_L) = \frac{r\bar{p}_L\hat{L}_0}{r-\mu} e^{-(r-\mu)t} - \left(\tilde{p}_L\hat{L}_0 + S\right)e^{-rt} \qquad (3.54)$$

Using (3.38), (3.42), and (3.54), one can rewrite the condition (3.53) as

$$V_0\left(t^*_{e,2}, \tilde{p}^*_{L,2}\right) - V_0\left(t_f, \tilde{p}^*_{L,M}\left(t_f\right)\right)$$

$$= e^{-rt_f}\left[\frac{\tau}{r}\left(e^{rd} - 1\right) - \left(\bar{p}_L\hat{L}_0 e^{\mu t_f} - S\right)\right] \qquad (3.55)$$

$$- \frac{\mu\bar{p}_L\hat{L}_0}{r-\mu}\left[e^{-(r-\mu)t_f} - e^{-(r-\mu)t^*_e}\right] > 0$$

The first term of the RHS is the discounted value of the difference between the owner's asking price and the buyer's offer price at t_f. This is the additional cost that must be added to the buyer's offer price to make it possible for the buyer to enter at t_f rather than at $t_{e,2}^*$. From (3.40), one can see that the second term is the difference in the value of the firm between entering at t_f and entering at $t_{e,2}^*$ when it takes the optimal price at each entry time. This can be interpreted as the benefit of entering at t_f rather than at $t_{e,2}^*$. Hence the condition (3.55) means that the cost of entering at t_f rather than at $t_{e,2}^*$ is greater than its benefit. If this is the case, then the buyer has no incentive to enter earlier.

Notable is that condition (3.52) is implied by (3.55) because the second term in (3.55) is positive. Hence (3.55) is the necessary and sufficient condition for the property not to be traded directly. In other words, the negation of the condition (3.55) is the necessary and sufficient condition for the direct trade of the property. Formally, if the following condition holds, then a direct trade is accomplished either before or at the forfeiture time:

$$\begin{aligned} V_0\left(t_{e,2}^*, \tilde{p}_{L,2}^*\right) - V_0\left(t_f, \tilde{p}_{L,M}^*\left(t_f\right)\right) \\ = e^{-rt_f}\left[\frac{\tau}{r}\left(e^{rd}-1\right) - \left(\bar{p}_L\hat{L}_0 e^{\mu t_f} - S\right)\right] \\ - \frac{\mu\bar{p}_L\hat{L}_0}{r-\mu}\left[e^{-(r-\mu)t_f} - e^{-(r-\mu)t_{e,2}^*}\right] \leq 0 \end{aligned} \tag{3.56}$$

A direct trade is accomplished before forfeiture if (3.51) is met as well, and it is done at the forfeiture time if the condition (3.56) is met but (3.51) is not. In a nutshell, NEs in the direct trade are summarized as follows:

$$\left\{\left(t_{e,1}^*, \tilde{p}_{L,1}^*\right)\right\} = \begin{cases} \left\{\left(t_{e,C}^*, \tilde{p}_{L,C}^*\right)\right\} \cap \left\{\left(t_{e,M}^*, \tilde{p}_{L,M}^*\right)\right\} \text{ if (3.51) is met} \\ \left\{\left(t_f, \frac{\tau}{r\hat{L}_0}\left(e^{rd}-1\right)\right)\right\} \text{ if (3.56) is met, but (3.51) is not met} \end{cases}$$

where $\left(t_{e,1}^*, \tilde{p}_{L,1}^*\right)$ denotes a NE in the direct trade.

Now look at the condition (3.55) in more detail. Let ψ_1 and ψ_2 denote the first and the second terms of the RHS in (3.55), respectively. Then substituting (3.8) for t_f and (3.37) for t_e^* yields

$$\psi_1 = \left[\frac{\tau}{r}\left(e^{rd} - 1\right) + S\right]\left[\frac{\tau(1-\gamma)e^{rd}}{(r+\delta)\gamma b\widehat{K}_0}\right]^{\frac{r}{\mu_x}} - \bar{p}_L\hat{L}_0\left[\frac{\tau(1-\gamma)e^{rd}}{(r+\delta)\gamma b\widehat{K}_0}\right]^{\frac{r-\mu}{\mu_x}}$$

$$\psi_2 = \frac{\mu\bar{p}_L\hat{L}_0}{r-\mu}\left\{\left[\frac{\tau(1-\gamma)e^{rd}}{(r+\delta)\gamma b\widehat{K}_0}\right]^{\frac{r-\mu}{\mu_x}} - \left[\frac{\bar{p}_L\hat{L}_0(r-\mu)}{rS}\right]^{\frac{r-\mu}{\mu}}\right\}$$

Letting $\psi = \psi_1 - \psi_2$ and rearranging yields

$$\psi = \left[\frac{\tau}{r}\left(e^{rd} - 1\right) + S\right]\left[\frac{\tau(1-\gamma)e^{rd}}{(r+\delta)\gamma b\widehat{K}_0}\right]^{\frac{r}{\mu_x}} - \frac{r\bar{p}_L\hat{L}_0}{r-\mu}\left[\frac{\tau(1-\gamma)e^{rd}}{(r+\delta)\gamma b\widehat{K}_0}\right]^{\frac{r-\mu}{\mu_x}}$$
$$+ \frac{\mu\bar{p}_L\hat{L}_0}{r-\mu}\left[\frac{\bar{p}_L\hat{L}_0(r-\mu)}{rS}\right]^{\frac{r-\mu}{\mu}}$$

One can show that the following comparative statics hold when (3.52) is met:

$$\frac{\partial\psi}{\partial\tau} > 0, \quad \frac{\partial\psi}{\partial d} > 0\,, \quad \frac{\partial\psi}{\partial S} > 0, \quad \frac{\partial\psi}{\partial\mu} < 0, \quad \frac{\partial\psi}{\partial\bar{p}_L} < 0$$

In other words, the likelihood of a lack of direct trade – and hence the likelihood of property forfeiture – is the higher the greater the property tax rate, the longer the grace period, and the greater the cost involved in converting property from industrial to commercial use. Also, it is the higher, the lower the growth rate of the commercial sector and lower the stationary price of existing properties. Of these parameters, the growth rate μ of the commercial sector is important because ψ_1 and ψ_2 are both largely determined by it. A very low value of this parameter makes ψ positive.

3.4.3.3 Operating Value in Equilibria

Now compute the value of operating a commercial firm on the legacy property. Since it is hard to get an analytical solution for the direct trade, look only at the cases of the sale by the local government. Substituting the property prices in (3.45) and (3.50) into (3.40) yields the value of the firm as

$$V_0 = \begin{cases} -\frac{l\hat{L}_0}{r-\mu}e^{-(r-\mu)T} + \frac{\mu S}{r-\mu}e^{-rT} + \frac{\mu}{r-\mu}\left(\bar{p}_L\hat{L}_0\right)^{\frac{r}{\mu}}\left(\frac{r-\mu}{rS}\right)^{\frac{r}{\mu}-1} & \text{if } t_{e,2}^* > t_f \\ -\frac{l\hat{L}_0}{r-\mu}e^{-(r-\mu)T} + \frac{\mu S}{r-\mu}e^{-rT} + \frac{\mu\bar{p}_L\hat{L}_0}{r-\mu}\left[\frac{\tau(1-\gamma)e^{rd}}{(r+\delta)\gamma b\hat{K}_0}\right]^{\frac{r-\mu}{\mu_x}} & \text{if } t_{e,2}^* = t_f \end{cases}$$

In an infinite horizon, one can obtain the value per unit size of property as follows:

$$\lim_{T\to\infty}\frac{V_0}{\hat{L}_0} = \begin{cases} \frac{\mu(\bar{p}_L)^{\frac{r}{\mu}}}{r-\mu}\left[\frac{\hat{L}_0(r-\mu)}{rS}\right]^{\frac{r}{\mu}-1} & \text{if } t_e^* > t_f \\ \frac{\mu\bar{p}_L}{r-\mu}\left[\frac{\tau(1-\gamma)e^{rd}}{(r+\delta)\gamma b\hat{K}_0}\right]^{\frac{r-\mu}{\mu_x}} & \text{if } t_e^* = t_f \end{cases}$$

One can see that the value function is increasing in the stationary price of existing properties, $\bar{p}_L$, as expected. A high stationary price of the property itself means a high value of operating a firm, and thus the entry is more profitable. Next, the value per unit size of property is decreasing in conversion costs per unit size of property and property size due to the convexity of conversion costs. However, this is true only for the trade after forfeiture. They do not matter in the trade at the moment of forfeiture.

3.4.3.4 Summary of Equilibria

In the process of industrial restructuring, legacy capital may follow four different paths depending on parameter values: Direct trade by the original owner before forfeiture, direct trade at forfeiture, trade by the local government at forfeiture, and trade by the local government after forfeiture. The four paths each have their own equilibria. These situations can be illustrated using diagrams with the three players' offer curves for the property price and time of sale.

Each of the three players in the property trading game has its own offer curves with selling price and time as illustrated in Figure 3.1. First, the manufacturing firm's (MF) offer price is decreasing in selling time as shown in (3.43). She has no right for the property after forfeiture, and thus her offer curve for that part is drawn as a dashed line. Second, the commercial entrepreneur (CE) offers a higher price as time passes as shown in (3.39), as the commercial sector is growing. Third, the local government's (LG) offer price is also increasing in selling time or a single point as shown in (3.46). As it has no right for the property before forfeiture, its offer curve is meaningful only for $t \geq t_f$. If the meaningful segment of its increasing offer curve does not intersect with the buyer's offer curve, the curve collapses into a single point so that it may intersect with the buyer's curve at $t = t_f$. Figure 3.1 is an example for a set of the three offer curves. Using this diagram, let's look at the above mentioned three equilibria of the trading game for the property in turn.

First, consider the case of direct trade before forfeiture. This case is illustrated in Figure 3.1, which shows that the buyer's and seller's offer curves meet before forfeiture as per (3.51). The equilibrium price and selling time $(t^*_{e,1}, \tilde{p}^*_{L,1})$can be derived numerically as discussed in Section 3.4.3.2. The local government plays no role; there is no abandonment; and the buyer purchases the property for the sum of the liability of unpaid taxes plus interest and the discounted profit from operating the manufacturing firm for the remaining period.

Second, consider the direct trade at the moment of forfeiture. Even though the buyer's and seller's offer curves do not meet before forfeiture, a direct trade is possible if the value of market entry with price $\tilde{p}^*_{L,M}(t_f)$ at t_f is higher than the value of market entry with price $\tilde{p}^*_{L,2}$ at $t^*_{e,2}$. In this case, the buyer's offer curve collapses into a single point as illustrated in Figure 3.2.

The NE is simply that point, that is, $\left(t_f, \tilde{p}_{L,M}^*(t_f)\right)$. The local government plays no role, but its existence makes the buyer change its offer.

Third, consider the case of trade by the local government at the moment of forfeiture. This occurs when the buyer's offer curve meets neither the manufacturing firm's offer curve nor the local government unconstrained offer curve as formally given in (3.48) and (3.52). Then the local government takes the constrained strategy and a trade takes place at the moment of forfeiture as shown in Figure 3.3. The price and selling time in equilibrium $(t_{e,2}^*, p_{L,2}^*)$ is shown in (3.49) and (3.50). In this case, the local government must accept a loss of the difference between the unpaid tax plus interest and the selling price. Formally, the loss by the local government is

$$LO_G = \tilde{p}_{L,s}(t_f) - \tilde{p}_{L,b}(t_f) = \frac{\tau}{r\hat{L}_0}\left(e^{rd} - 1\right) - \left(\bar{p}_L e^{\mu t_f} - \frac{S}{\hat{L}_0}\right) > 0$$

Of course, this loss must be taken as gains by the manufacturing firm and the commercial entrepreneur.

Fourth, consider the case of trade by the local government after forfeiture. This occurs when the buyer's offer curve does not meet the owner's offer curve but meets the local government's unconstrained asking price after forfeiture as given by (3.47) and (3.52). If the original owner and the buyer fail to reach a direct trade, the local government seizes the property and sells it to the buyer after a period of abandonment $(t_{e,2}^* - t_f)$. The selling price and time in equilibrium $(t_{e,2}^*, p_{L,2}^*)$ is shown in (3.44) and (3.45). In this case, one cannot rule out the possibility that the local government may experience a gain unlike in the second case. The present value of the selling price at the moment of forfeiture may be greater than the total unpaid tax plus interest. Formally,

$$LO_G = \tilde{p}_{L,s}(t_f) - \tilde{p}_L^*(t_e^*)e^{-r\left(t_e^* - t_f\right)} = \frac{\tau\left(e^{rd} - 1\right)}{r\hat{L}_0} - \frac{\mu S e^{-r\left(t_e^* - t_f\right)}}{(r-\mu)\hat{L}_0} \lesseqgtr 0$$

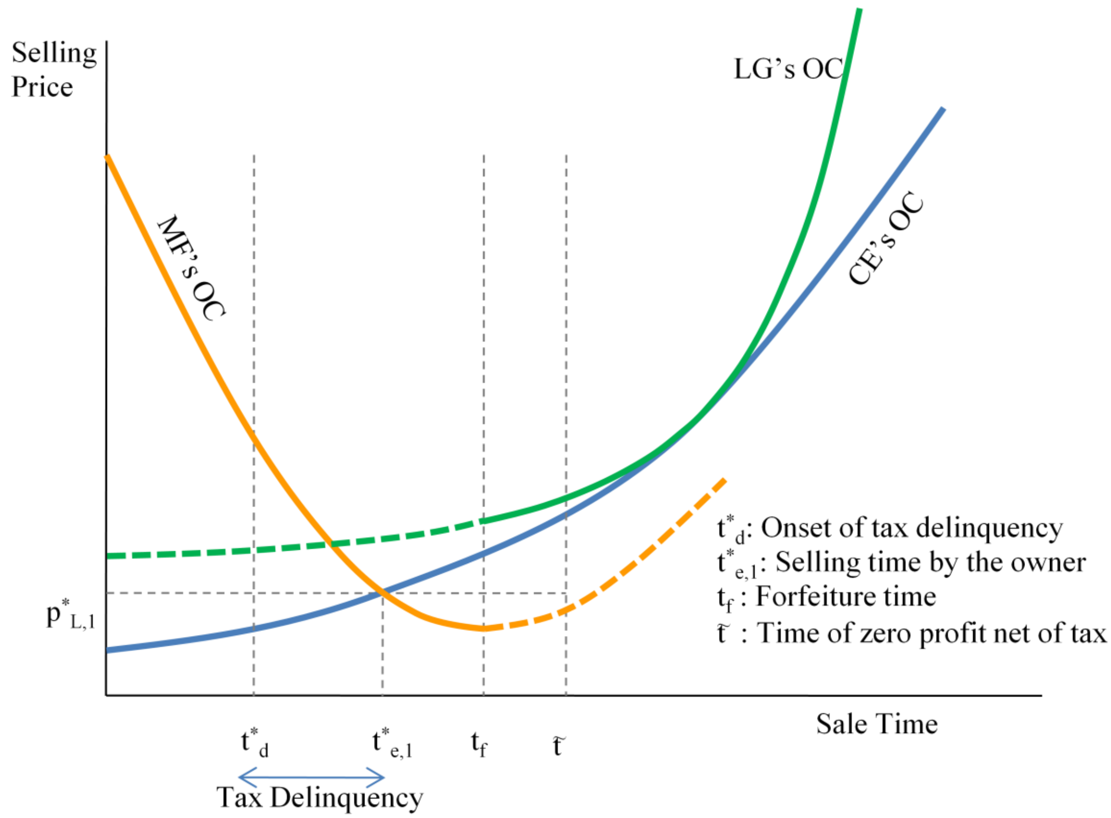

Figure 3.1: Direct Trade before Forfeiture

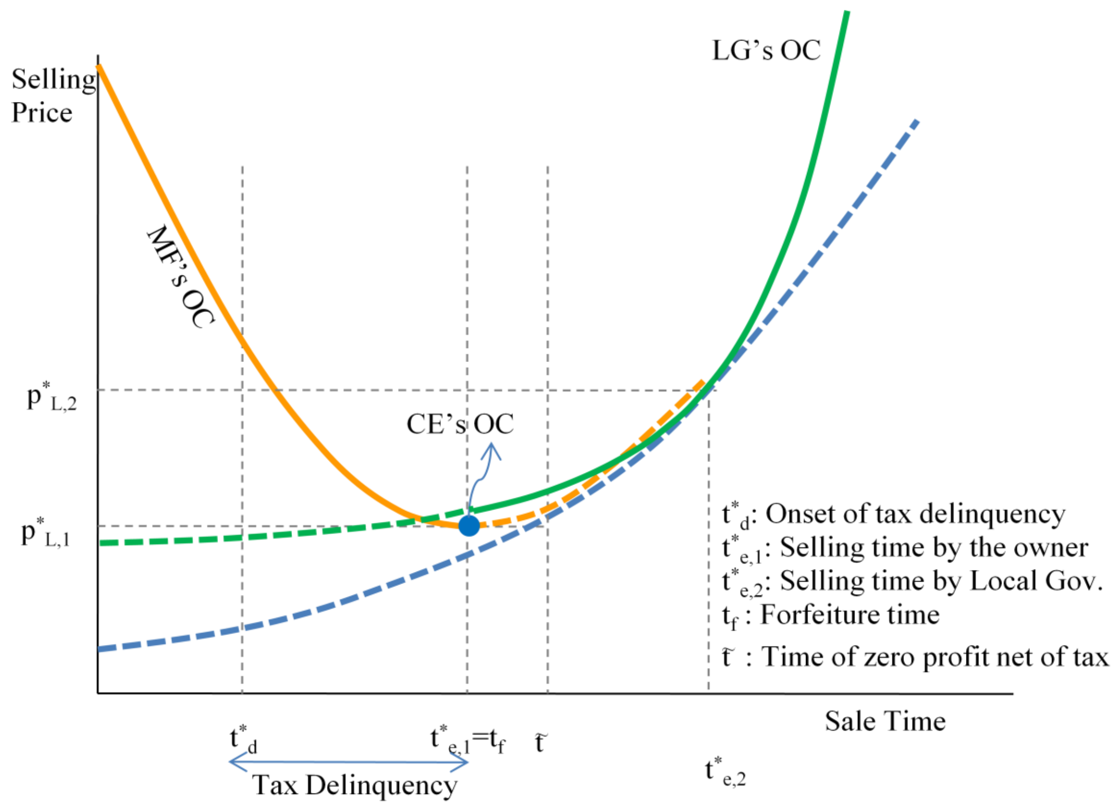

Figure 3.2: Direct Trade at Forfeiture

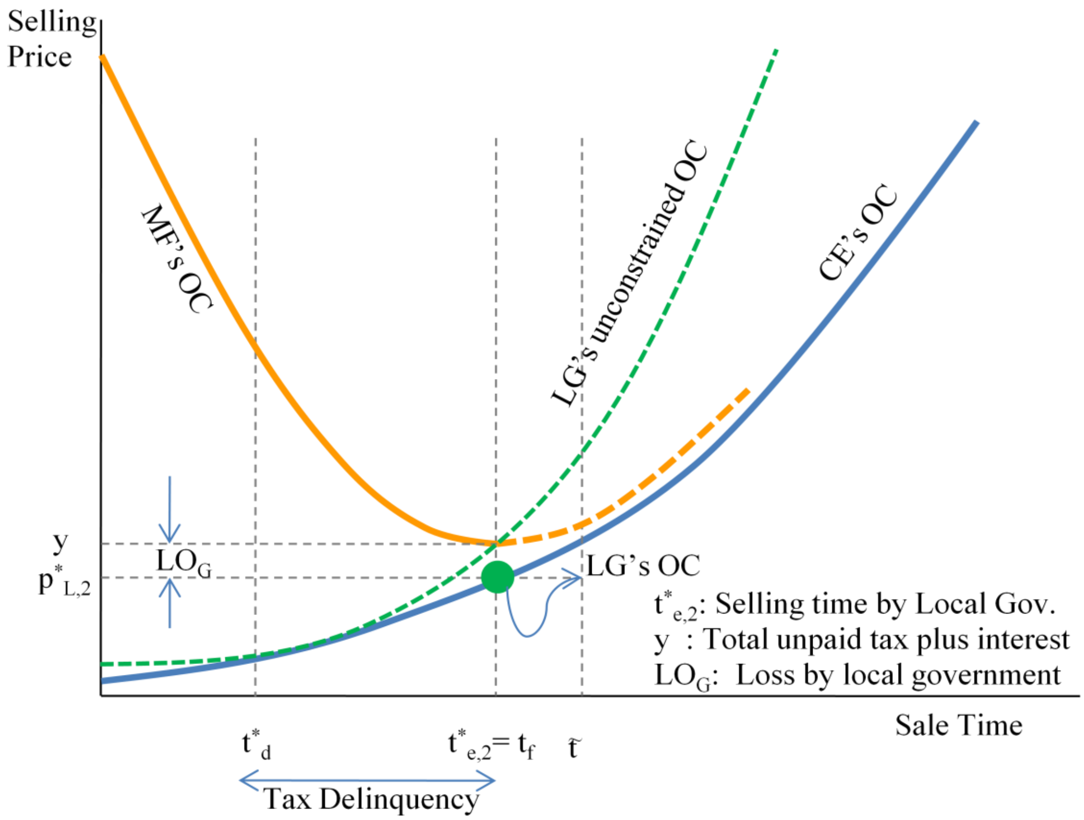

Figure 3.3: Sale by Local Government at Forfeiture

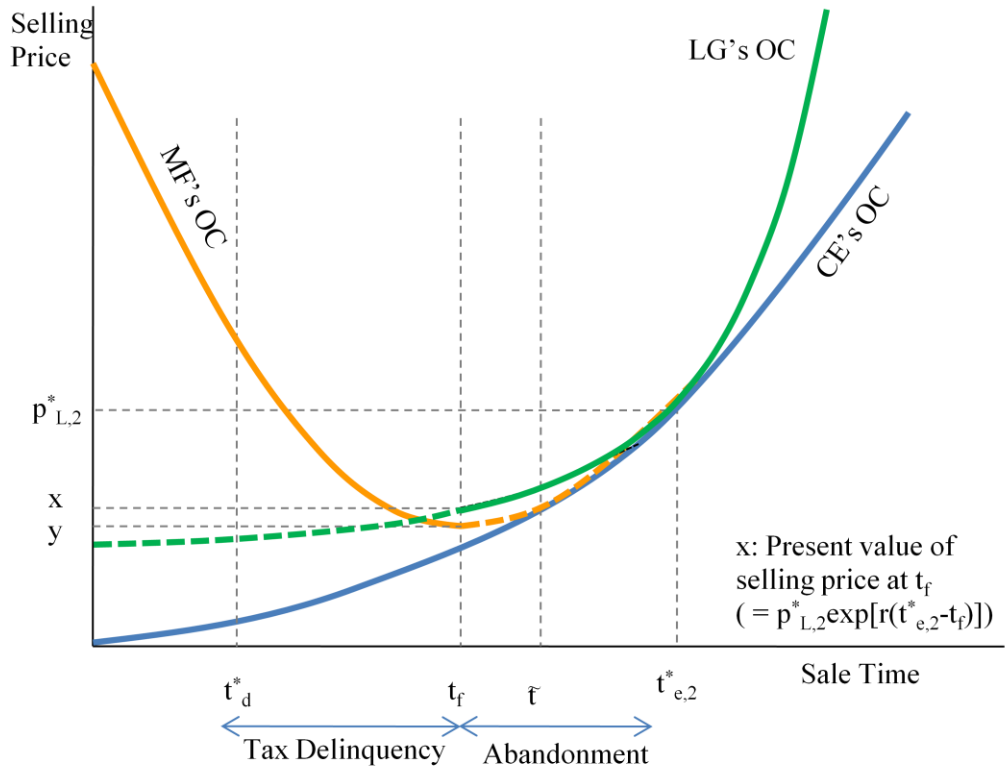

Figure 3.4: Temporary Abandonment

Now let's summarize the quilibria in the trading game for the legacy property. The equilibrium in this game is either $(t_{e,1}^*, \tilde{p}_{L,1}^*)$ or $(t_{e,2}^*, \tilde{p}_{L,2}^*)$ depending on whether a trade direct is achieved or not between the manufacturing and the buyer. If the condition (3.51) is met and the direct trade is achieved, then the former is the equilibrium. Otherwise, the letter is the equilibrium. Let $(t_e^*, \tilde{p}_L^*)$ denote the NE of this game. Then it can be written as

$$(t_e^*, \tilde{p}_L^*) = \begin{cases} (t_{e,1}^*, \tilde{p}_{L,1}^*) & \text{if } V_0(t_{e,2}^*, \tilde{p}_{L,2}^*) \le V_0(t_f, \tilde{p}_{L,M}^*(t_f)) \\ (t_{e,2}^*, \tilde{p}_{L,2}^*) & \text{otherwise} \end{cases}$$

The equilibrium for the direct trade is numerically obtained using the two parties' offer curves as discussed in 2.4.3.2. The equilibrium for the trade by the local government is given by (3.44)-(3.50). Under the condition (3.47), price (3.45) and selling time (3.44) constitute a NE, while (3.49) and (3.50) constitute an equilibrium under the condition (3.47).

One can integrate the equilibria of (3.44)- (3.50) into a simple form as follows:

$$t_{e,2}^* = \max\left\{\frac{1}{\mu}\log\frac{rS}{\bar{p}_L\hat{L}_0(r-\mu)}, \frac{1}{\mu_x}\log\left[\frac{(r+\delta)\gamma b\hat{K}_0}{\tau(1-\gamma)}\right] - \frac{r}{\mu_x}d\right\} \tag{3.57}$$

$$\tilde{p}_{L,2}^* = \max\left\{\frac{\mu S}{(r-\mu)\hat{L}_0}, \bar{p}_L\left[\frac{(r+\delta)\gamma b\hat{K}_0}{\tau(1-\gamma)e^{rd}}\right]^{\frac{\mu}{\mu_x}} - \frac{S}{\hat{L}_0}\right\} \tag{3.58}$$

The first term in the parenthesis of (3.57) is the selling time in equilibrium when it is greater than the forfeiture time by meeting the condition (3.47). The second term is the forfeiture time. The rule for equilibrium is that the selling time in equilibrium is the first term if it is greater than the other one, and if not, the second one. That is why the compact form in (3.57) is enough. Similarly, the first term in the parenthesis of (3.58) is the price in equilibrium if the selling time is greater than the forfeiture time by meeting the condition (3.47). If not, the second term is the price in equilibrium. But condition (3.47) is met if and only if the first term in (3.58) is greater than the second term. So the rule for the equilibrium price is that the selling price in equilibrium is the first term if it is greater than the other term, and if not, the second one. As a result, (3.58) is sufficient to describe the equilibrium price in the trade between the local government and the buyer.

3.4.4 Sensitivity Analysis

The pricing and entry times discussed above constitute Nash Equilibria for the game involving the local government and the buyer or the manufacturing firm and the buyer. The following looks at the sensitivity of these equilibria to changes in parameters. Since the abandoned property is of our interest, the focus is on the trade that involves the local government.

3.4.4.1 Entry Time

Consider changes in the entry time of the new commercial firm. First, the optimal entry time is advanced with a rise in the stationary price of commercial properties, $\bar{p}_L$.

$$\frac{\partial t_{e,2}^*}{\partial \bar{p}_L} < 0$$

If the price of existing properties is high, commercial firm start their business earlier, and indeed, if $\bar{p}_L$ is high enough to meet condition (3.48), then the property is sold even earlier, either prior to or at the time of forfeiture.

Second, the optimal entry time is delayed with rising conversion cost per unit size of property, $S/\hat{L}_0$.

$$\frac{\partial t_{e,2}^*}{\partial (S/\hat{L}_0)} > 0 \qquad (3.59)$$

The smaller the conversion cost is, the sooner the commercial firm enter. If the costs are small enough to meet the condition (3.48), then the property is sold even before or at the moment of forfeiture.

Third, the entry is advanced with a high discount (interest) rate r.

$$\frac{\partial t_{e,2}^*}{\partial r} < 0$$

In the trade after forfeiture, this is true because higher time preference makes the commercial firm enter sooner. In the trade at the time of forfeiture, this is also true[19] because the industrial firm tries to close the factory sooner with a high interest rate.

Lastly, the entry time is delayed with the size of the property $\hat{L}_0$ as follows:

$$\frac{\partial t_{e,2}^*}{\partial \hat{L}_0} = \frac{S'\hat{L}_0 - S + \frac{\partial \tilde{p}_L}{\partial \hat{L}_0}\hat{L}_0}{\mu(\tilde{p}_L\hat{L}_0 + S)\hat{L}_0} > 0 \tag{3.60}$$

The inequality of (3.60) holds due to the properties of the convex function S as suggested in (3.28).[20] A convex function of conversion costs makes the conversion per unit size of property rise with the property size, that is, $\partial(S/\hat{L}_0)/\partial\hat{L}_0 > 0$. Combined with the characteristics in (3.59), this leads to the same direction of changes.

3.4.4.2 Present Value of Property Price (PVP)

Next consider changes in the present value at time 0 of selling price (PVP). From (3.45), PVP is written as

$$PVP = \begin{cases} \mu\left(\frac{\bar{p}_L}{r}\right)^{\frac{r}{\mu}}\left[\frac{(r-\mu)\hat{L}_0}{S}\right]^{\frac{r}{\mu}-1} & \text{if } t_{e,2}^* > t_f \\ \bar{p}_L\left[\frac{(r+\delta)\gamma b\hat{K}_0}{\tau(1-\gamma)e^{rd}}\right]^{\frac{\mu-r}{\mu_x}} - \frac{S}{\hat{L}_0}\left[\frac{\tau(1-\gamma)e^{rd}}{(r+\delta)\gamma b\hat{K}_0}\right]^{\frac{r}{\mu_x}} & \text{if } t_{e,2}^* = t_f \end{cases} \tag{3.61}$$

First, the price rises with an increasing growth rate of the commercial sector μ, no matter whether the property is sold after or at the time of forfeiture, that is:

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[19] In order for this to be true, one needs a new condition $d > \frac{1}{r+\delta}$.

[20] The convexity of S implies $S'\hat{L}_0 - S > 0$ and $\frac{\partial \tilde{p}_L}{\partial \hat{L}_0} = \frac{\mu}{r-\mu}\frac{(S'\hat{L}_0 - S)}{\hat{L}_0^2} > 0$, and as a result $\frac{\partial t_e^*}{\partial \hat{L}_0} > 0$.

$$\frac{\partial PVP}{\partial \mu} > 0$$

If the new sector does not grow at all, then the selling price must fall to $\max(\bar{p}_L - s/\hat{L}_0, 0)$. So when conversion cost is very high, the price must be zero.

Second, the rate of decline of the manufacturing sector, μ_x matters only if the property is sold at the moment of forfeiture.

$$\frac{\partial PVP}{\partial \mu_x} < 0 \; only \; if \; t_e^* = t_f$$

A higher rate of decline leads to an earlier forfeiture, but at the early stage the buyer's affordable price is low. If the sale at the moment of forfeiture is optimal, then the local government has to accept the low price. Otherwise, the rate of decline of the closing sector does not matter any longer, as implied by (3.61).

Third, PVP declines with a rising discount rate.

$$\frac{\partial PVP}{\partial r} < 0$$

In the trade after forfeiture, this is true because holding the asset becomes more costly as the interest rate goes up, and thus its price should fall. In the trade at the time of forfeiture, this is also true because with higher interest rates, the industrial firm tries to close the factory sooner.

Fourth, the price falls with higher conversion costs per unit size of property in both cases.

$$\frac{\partial PVP}{\partial (S/\hat{L}_0)} < 0$$

High conversion costs lower the value of operating a commercial firm on the property, which in turn lowers the affordability of the buyer and thus the discounted price fall.

Lastly, the price falls with the size of the property in both cases due to the convexity of the function of conversion cost as shown for the case of (3.60).

$$\frac{\partial PVP}{\partial \hat{L}_0} < 0$$

If the conversion cost S is linear in the property size, $\hat{L}_0$, then the property size does not matter.

3.5 Alternatives to Market Equilibrium

3.5.1 An Alternative for Efficiency

This section summarizes the results so far, as they relate to abandonment and expands them, by considering the optimality of abandonment.

3.5.1.1 Abandonment Period

In general, if abandonment occurs, it is finite – at least as long as the commercial sector expands. Legacy property remains abandoned until it is sold to the commercial entrepreneur. In order for legacy property to be abandoned, there should not be a direct trade between the seller and the buyer and the local government must sell the property after forfeiture. As discussed in 2.4.3.4, (3.55) describes the condition for no direct trade and (3.47) does for the entry time later than forfeiture. Rewrite those conditions:

- No direct trade:

$$\left[\frac{\tau}{r}\left(e^{rd}-1\right)+S\right]\left[\frac{\tau(1-\gamma)e^{rd}}{(r+\delta)\gamma b\hat{K}_0}\right]^{\frac{r}{\mu_x}}+\frac{\mu\bar{p}_L\hat{L}_0}{r-\mu}\left[\frac{\bar{p}_L\hat{L}_0(r-\mu)}{rS}\right]^{\frac{r-\mu}{\mu}}$$
$$>\frac{r\bar{p}_L\hat{L}_0}{r-\mu}\left[\frac{\tau(1-\gamma)e^{rd}}{(r+\delta)\gamma b\hat{K}_0}\right]^{\frac{r-\mu}{\mu_x}}$$

- Entry later than forfeiture:

$$\frac{S}{\hat{L}_0} > \frac{\bar{p}_L(r-\mu)}{r}\left[\frac{(r+\delta)\gamma b\hat{K}_0}{\tau(1-\gamma)e^{rd}}\right]^{\frac{\mu}{\mu_x}}$$

A very large conversion cost makes the legacy property abandoned for some time. Using (3.8) and (3.44), the length of abandoned period is obtained as

$$t_A = t_{e,2}^* - t_f = \log\left[\frac{rS}{\bar{p}_L\hat{L}_0(r-\mu)}\right]^{\frac{1}{\mu}}\left[\frac{\tau(1-\gamma)e^{rd}}{(r+\delta)\gamma b\hat{K}_0}\right]^{\frac{1}{\mu_x}}$$

This suggests that the following conditions raise the length of the abandonment period for property released by the manufacturing sector:

- High conversion cost S $\left(\frac{\partial t_A}{\partial S} > 0\right)$;
- Large property size $\hat{L}_0$ $\left(\frac{\partial t_A}{\partial \hat{L}_0} > 0\right)$;
- Low growth rate of the newly coming sector μ_y or μ $\left(\frac{\partial t_A}{\partial \mu} < 0 \text{ for small } \mu^{21}\right)$;
- High decline rate of the old sector μ_x $\left(\frac{\partial t_A}{\partial \mu_x} > 0\right)$;
- Low stationary price of existing properties $\bar{p}_L$ $\left(\frac{\partial t_A}{\partial \bar{p}_L} < 0\right)$;
- High tax rate τ $\left(\frac{\partial t_A}{\partial \tau} > 0\right)$; and
- Long grace period for tax delinquency d $\left(\frac{\partial t_A}{\partial d} > 0\right)$.

These results seem consistent with reality and match expectations. First, the conversion of industrial capital to alternative uses almost always requires high conversion costs. The higher these conversion costs, the longer the abandonment period. Second, a large property is more difficult to convert to another use and thus it remains abandoned longer. Third, as one would

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[21] $\frac{\partial t_A}{\partial \mu} = \frac{1}{\mu^2}\left[\log(r-\mu) + \frac{\mu}{r-\mu}\right]$. When μ is almost as great as r, the sign changes, that is, $\partial t_A/\partial \mu > 0$. For most values smaller than r, however, the given relation holds because the first term is dominant over the second one.

expect, the abandonment period lengthens if the downturn of the outgoing sector turns more severe, as expressed by its rate of decline; and it also lengthens, if there are fewer alternative uses, i.e. if the rate of growth of the incoming sector is low. If the growth rate is zero, the abandonment period has to be infinite. Fourth, as expected, abandonment would be expected to last longer, if the stationary capital price is low. A low price means less demand for legacy capital, and a low demand translates into longer periods of idleness. Fifth, policy variables such as tax rate and grace period can also impact the abandonment. High taxes lead to an early shut-down (or forfeiture) of the outgoing sector because profit net of tax becomes zero sooner than would be the case with lower taxes. A longer grace period has a similar effect. It advances the onset of tax delinquency and forfeiture as implied by (3.11)and (3.12).

3.5.1.2 Efficient Use of Legacy Property

An allocation of legacy capital is efficient if the total output from the capital is maximized. The efficiency requires that the capital be converted when the instantaneous profit in the declining manufacturing sector, ϕ_M fall below that of the growing commercial sector, ϕ_C. The optimum arises when the instantaneous profit in the two sectors are equal. Formally, the efficiency condition is written as

$$\phi_M(t_S^*) = \phi_C(t_S^*) \tag{3.62}$$

where t_S^* is the optimal conversion time. Hence, the abandonment of legacy property must be a wasteful as long as the profit remains positive.[22] While it may be a private optimum it is not efficient.

Since ϕ_M is the operating profit net of user costs of capital as shown in (3.9), it is written

[22] If a fixed maintenance cost is incurred by the manufacturing firm, the operation profit on the legacy property can go down below zero at some point. In that case, abandonment can be efficient.

$$\phi_M = \frac{(r+\delta)\gamma b\widehat{K}_0}{1-\gamma} e^{-\mu_x t}$$

ϕ_C is the operating profit net of user costs of capital and annuity of conversion cost.[23]

$$\phi_C = \tilde{\pi}(t; \hat{L}_0) - (r+\rho)p_K\widetilde{K}_t - rS$$

Substituting (3.34) for $\tilde{\pi}(t; \hat{L}_0)$ and (3.33) for $\widetilde{K}_t$ yields

$$\phi_C = r\bar{p}_L\left(\frac{A_t}{A_0}\right)^{\epsilon}\hat{L}_0 e^{\mu t} - rS = r\hat{L}_0\tilde{p}_{L,b}$$

For simplicity assume that TFP does not vary over time, that is, $A_t = A_0$. Then the optimal conversion time t_S^* is derived from the efficiency equation (3.62). In general, it is not easy to solve the equation analytically, but for a special case with $S = 0$, the optimum conversion time is solved as

$$t^* = \frac{1}{\mu_x + \mu}\left[\mu_x\tilde{t} - \log\frac{r\bar{p}_L\hat{L}_0}{\tau}\right]$$

where $\tilde{t}$ is the time when profit net of tax becomes zero in the manufacturing sector as shown in (3.10).[24] For other cases with $S > 0$, one can readily see that it is greater than that in the case of zero conversion cost, that is,

$$t_S^* > t^*$$

In general, this efficient time must be different both from the closure (forfeiture) time t_f and the entry time $t_{e,2}^*$. In the interesting case of abandonment, the efficient time always later than the closure time while it is ambiguous whether it is earlier than the entry time or not, see the following propositions:

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[23] The time horizon is assumed to be infinite for simplicity. Then the annuity of conversion cost is *rS*.

[24] Suppose as usual that the property tax rate is smaller than interest rate. Then the second term in the parenthesis must be positive, and hence $t^* < \tilde{t}$.

Proposition 1 *If there is abandonment, then the closure of the manufacturing firm is earlier than the efficient conversion time.*

<Proof>

Using (3.52), the proposition is written as

$$t_S^* > t_f \text{ if } \frac{\tau}{r\hat{L}_0}(e^{rd} - 1) > \bar{p}_L e^{\mu t_f} - \frac{S}{\hat{L}_0}$$

It is obvious that $t_S^* > t_f$ is equivalent to $\phi_M(t_f) > \phi_C(t_f)$. Hence showing $\phi_M(t_f) > \phi_C(t_f)$ is sufficient to establish the proposition. Substituting (3.8) for t_f yields

$$\phi_M(t_f) = \tau e^{rd}$$

$$\phi_C(t_f) = r\hat{L}_0\left(\bar{p}_L e^{\mu t_f} - \frac{S}{\hat{L}_0}\right)$$

The given condition implies

$$\phi_C(t_f) < \tau(e^{rd} - 1) < \phi_M(t_f)$$

That is what is supposed to be shown. ■

Proposition 2 *If the conversion cost is large enough to satisfy* $S > \frac{r-\mu}{r\mu}$ *and the condition for entry later than forfeiture in (58), then the entry of the commercial firm is later than the efficient conversion time.*

<Proof>

One has only to show $\phi_C(t_{e,2}^*) > \phi_M(t_{e,2}^*)$, equivalently,

$$\frac{r\mu S}{r-\mu} > \frac{(r+\delta)\gamma b\hat{K}_0}{\tau(1-\gamma)e^{rd}}\left[\frac{rS}{\bar{p}_L\hat{L}_0(r-\mu)}\right]^{-\frac{\mu_x}{\mu}}$$

But (58) implies that the RHS is smaller than unity while the given condition for the conversion implies that the LHS is greater than unity. Hence we are done. ■

These propositions tell us that the closure of the outgoing sector is too early and the entry of the incoming sector is too late, compared to the optimum for conversion. The following diagram illustrates an example for that. In this example, the efficient conversion time is between the closure of the manufacturing firm and the entry of the commercial firm, that is, $t_f < t_S^* < t_{e,2}^*$. As a result, in the market solution, the property will be abandoned during $\left(t_f, t_{e,2}^*\right)$, which is socially wasteful.

Why do these distortions take place? One may think that the inefficiency is related to large fixed costs, taxation, and the nature of the game. Let's look at them in turn, even though the first turns out not to be a true source of the distortions.

First, a large fixed conversion cost delays the entry of the commercial firm and lengthens the abandonment period, if any, which does not necessarily mean inefficiency. A large fixed cost of conversion shifts down the profit curve of the commercial firm and hence the commercial entry time should be delayed for a given price of the property. No matter how large the fixed cost is, however, the profit rise above the fixed cost plus the property price. As long as the property is not forfeited until then and the asking price is exactly what the commercial entrepreneur is willing to accept at the efficient conversion time t_S^*, nothing prevents the conversion from occurring at that time. The key does not lie in the commercial sector.

Then what about a fixed maintenance cost with the manufacturing firm? Even though it has not been modeled in the current version of the model, its effects on abandonment of legacy capital are analogous to those of the property tax. One can regard the property tax τ as a fixed maintenance cost. Then the manufacturing profit shifts down by the fixed cost τ in Figure 3.5. In this case, of course, there is nothing analogous to a tax delinquency. The firm closes at $\tilde{t}$ rather than t_f if a sale to the commercial enterprise is not yet possible. Otherwise the property is sold to the commercial firm before t_f without abandonment. Whether abandonment occurs depends on the size of the fixed maintenance cost relative to the level of manufacturing profit. If the profit goes down below the maintenance cost before the new commercial firm enters, the property should remain abandoned. However, abandonment in this case is efficient from the perspective of the whole resources including the lump-sum cost of conversion, because it is socially wasteful to invest too many resources (lump-sum cost for conversion) when there is not enough demand.

Both a fixed maintenance cost and a lumpy conversion cost contribute to and potentially lengthen the period of abandonment. However, this abandonment is efficient – as long as abandonment is not associated with negative externalities. This is different from abandonment in the presence of the following real sources of distortion, taxation and the nature of trading game.

Next, consider the fixed property tax. If it were not for property tax and a fixed maintenance cost, then the property would not be abandoned but traded at the efficient conversion time t_S^*. The property tax makes the manufacturing firm close earlier than the efficient point. Moreover, the grace period, combined with positive interest rate, further advances the closure. If the local government did not allow tax delinquency, then the firm should close exactly at $\tilde{t}$ when its net profit is zero. The property tax has nothing to do with the use of the property and thus distort the decision of economic agents in the model. The effect of taxation on the abandonment of the legacy property is characterized in Section 3.5.1.1.

Lastly, consider the nature of the bilateral trading game. As long as the trading game is played by the manufacturing firm and the commercial entrepreneur, the outcome of the game is efficient. In other words, the efficient outcome is equivalent to a Pareto Optimum. One can readily show that the solution of the game leads to the efficient conversion time indeed. If the local government participates in the game as the seller, however, the nature of the game becomes different from the game between the two private agents. The local government does not take into account the profit of the manufacturing sector anymore, and hence the efficiency equation

$\phi_M = \phi_C$ does not hold generally. As a result, the conversion of the property should occur at $t^*_{e,2}$ in (3.44), which is different from the efficient time for conversion, t^*_S. Be the entry time later or earlier than the efficient time, it always leads to a social loss.

As the sources of distortion lies with the local government, it can recover efficiency by adjusting the property tax and its asking price in the game. Lowering the property tax leads to a delay in the closure of the manufacturing firm, and a proper price induce the commercial firm to enter at the efficient time t^*_S. t^*_S. Figure 3.5 illustrate that a property tax τ^* and price p^*_L achieves the efficient conversion of the property. Of course, the tax delinquency must not be allowed because it leads to too an early shut-down of the plant.

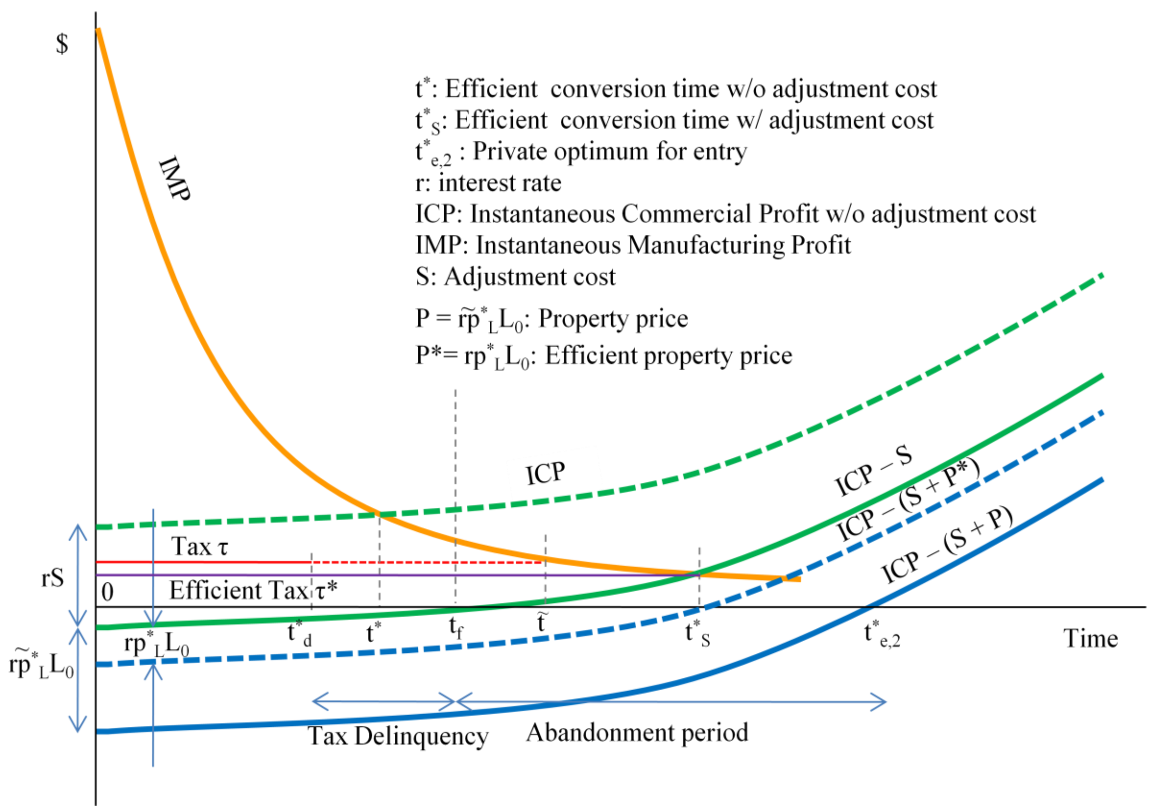

Figure 3.5: Efficient Conversion of Legacy Property

3.5.2 An Alternative for Social Welfare

3.5.2.1 Negative Spillovers of Abandonment

Another source of market failure is the well-known externalities associated with abandoned properties. Abandonment results in numerous disamenities: Abandoned properties often become a hotbed of crime, a fire risk, and a haunt for rodents; they reduce economic activities in neighboring areas; and their physical deterioration and visual blight often tends to impair the productive use of surrounding areas. Productivity declines, both because of the impact on neighboring properties and because of the threat to educated workers, who tend to leave the city to avoid its disamenities.

For now we keep our eyes on the productivity effects of abandoned properties. Lower productivity due to abandonment leads to lower investment and a lower operating profit in the newly growing sector. This in turn leads to late entry, because the profit in the early stage is not yet high enough to overcome the high fixed cost of conversion.

The sensitivity of the entry time to productivity can be investigated by relaxing the assumption of no change in productivity in Section 3.4.2.1, where the optimal entry time of the commercial firm was calculated based on the assumption that there is no change in the environment. If there is a change in the productivity due to environmental change such as an increase in abandonment, then one cannot drop the productivity ratio $(A_t/A_0)^\epsilon$ in the expressions for the path of capital, labor, investment, and productivity in (3.33) through (3.35). In turn, it should enter the objective functional of the dynamic program (3.29). Since the term varies over time according to the changes in the environment, it is generally impossible to come up with closed forms for the value of the firm and the optimal entry time, as we did in Section 3.4.2.1. However, the following simple case will be sufficient to illustrate the effect of lower productivity.

Suppose that the environment suffers, say from an increase in abandonment, and this state lies within the firm's planning horizon. Also assume that the commercial firm's productivity has only two values: A_0 for good state, and A_L for bad state. Obviously $A_0 > A_L$, and hence $(A_t/A_0)^{\epsilon} = (A_L/A_0)^{\epsilon} < 1$ for all time t. As this term is not unity but still a constant, one can readily calculate the value of the firm by substituting (3.33), (3.34) and (3.35) into the objective functional of the program (3.29).

$$\tilde{V}_0 = \frac{l\tilde{L}_0}{\mu - r}\left(\frac{A_L}{A_0}\right)^{\epsilon}\left[e^{(\mu-r)T} - e^{(\mu-r)t_e}\right] + \tilde{p}_L\tilde{L}_0 e^{-rT} - \left(\tilde{p}_L\tilde{L}_0 + S\right)e^{-rt_e} < V_0$$

Since $(A_L/A_0)^{\epsilon} < 1$, the value of the commercial firm is smaller in bad state than the value in a good state. To derive the optimal entry time, take the first derivative and equate it to zero. Then the new solution is obtained as

$$\tilde{t}_{e,2}^{*} = \frac{1}{\mu}\log\frac{\tilde{p}_L\hat{L}_0 + S}{\frac{\bar{p}_L\hat{L}_0}{1-\alpha-\beta}\left[(1-\beta)\left(\frac{A_L}{A_0}\right)^{\epsilon} - \alpha\right]} > t_{e,2}^{*} \tag{3.63}$$

This is the new strategy of the commercial entrepreneur in bad state influenced by negative externalities of abandonment. While the commercial firm's strategy is influenced by the loss in productivity, the local government's strategy to maximize the revenue from the sale of the property does not change at all as implied by (3.41). In other words, $\tilde{p}_L$ in the numerator does not change even if abandonment has negative externalities. That is why the inequality in (3.63) holds. In short, a decline in productivity due to abandonment leads to a delay in the entry time.

Notable is that delays in the entry of firms cause more abandonment in the city as a whole and this worsen the current state. Accordingly more firms delay their entries. It turns out that externalities associated with individual firms' behavior constitute changes in the whole environment. Hence changes in the environment should be modeled so that they can be determined endogenously.

These effects may be investigated using numerical simulation. (3.60) tells us that the optimal entry time is delayed as property size rises. If a mass of properties of the same characteristics except size are freed by the declining sector at one time, then they will be converted into a new use beginning from the small property. Accordingly the vacancy rate will decline over time. If productivity is a function of vacancy, then it will increase over time. As a result, the conversion will be delayed in the beginning, while it will accelerate as time passes by, though the vacancy is still higher than it would be otherwise, due to externalities.

3.5.2.2 Social Welfare and Urban Growth

The previous section has introduced negative externalities associated with abandonment. However, the local government still behaved as an asset manager only. It maximized the revenue from the sale of the forfeited property, but not a broader welfare function considering the cost to society of abandonment externalities. The following introduces such a welfare function, and considers its optimization.

Specifically, let the social welfare function be the utility function of a representative worker:

$$W_t = F\left(w, \mathbb{N}_t, \zeta\mathbb{L}_t, \tilde{p}^*_{L,2}(t)\mathbb{B}_t, \mathbb{A}_t\right)$$

where w is wage rate, $\mathbb{N}_t$ is the total population, ζ is property tax rate, $\mathbb{L}_t$ is total size of taxable property, $\tilde{p}^*_{L,2}$ is the asking price of forfeited properties, $\mathbb{B}_t$ is total size of forfeited properties that is sold at time t, and $\mathbb{A}_t$ is the total size of abandoned properties at time *t*.

Obviously her utility rises with her wage income. The population size increases her quality of life due to agglomeration economies, other things being equal. Her utility also rises with public service per capita, which is increasing in its property tax revenue and revenue from selling forfeited properties. Hence the two sources of revenue increase her utility. Lastly abandoned properties have negative spillovers on her quality of life. In short, the following signs must hold:

$$\frac{\partial W_t}{\partial w} > 0, \frac{\partial W_t}{\partial \mathbb{N}_t} > 0, \frac{\partial W_t}{\partial \zeta \mathbb{L}_t} > 0, \frac{\partial W_t}{\partial \tilde{p}^*_{L,2}(t)\mathbb{B}_t} > 0, \frac{\partial W_t}{\partial \mathbb{A}_t} < 0$$

The local government's new problem then is to maximize the discounted social welfare by choosing a property tax rate and the selling price of forfeited property:

$$\max_{\zeta, \tilde{p}_{L,2}} \int_0^\infty W_t e^{-rt} \, dt$$

$$\text{s.t. } \mathbb{N}_t(\zeta, \tilde{p}_{L,2}), \mathbb{L}_t(\zeta, \tilde{p}_{L,2}), \mathbb{A}_t(\zeta, \tilde{p}_{L,2}), \text{and } \mathbb{B}_t(\zeta, \tilde{p}_{L,2}) \text{ are given}$$

To simplify the problem, the rule for the asking price of forfeited properties can be assumed to be the same as the revenue maximizing municipality's rule. Then the problem is reduced to the problem of choosing the optimal level of the property tax rate. From the discussion in Sections 3.4 and 3.5, it follows that a high property tax rate reduces employment, leading to a low population size and to a low taxable property size. With a high property tax rate, $\mathbb{B}_t$, i.e. the sale schedule for forfeited property, is delayed as the abandonment period is lengthened. Taking these factors into account, the local government must choose an optimal tax rate.

Nothing prevents negative abandonment externalities from being taken into account as long as the calculations are computable. Introducing a simple form for the social welfare function and employing the simulation method suggested in Section 3.5.2.1 makes it possible to determine the optimal property tax rate.

The impact on population growth of the local government' optimal policy is ambiguous and depends upon the form of social welfare function. This ambiguity in sign arises from the fact that a high property tax not only improves service level but also reduces employment and thus lowers population size with a negative effect on agglomeration economies. The local government must tradeoff gains from public service improvements against amenity gains from agglomeration economies. If the first one is dominant, it should raise the tax rate and shift down the population growth path. Otherwise, it should lower the rate and shift up the path. As a result, the impact of the optimal policy on growth remains open and depends on the relative dominance of the two utility factors, public service level versus agglomeration economies. The numerical implementation of these ideas is left for a future paper.

3.6 Conclusion

The model shows how legacy property is abandoned in the process of industrial restructuring, and how it is converted to a new use. It explains why abandoned properties have a positive price in a certainty world. It explains how buildings may be abandoned when faced with large tax debt, and how they later may be converted to other uses. The main sources of distortion are taxation, and negative spillovers from abandonment. These factors make market outcomes deviate from efficiency and social optimum.

Sensitivity analysis shows that the abandonment period of legacy capital increases with the conversion cost for conversion, the size of legacy capital and the rate of decline of the outgoing sector, and it decreases with the growth rate of the remaining sector. Abandonment becomes infinite when the growth rate is zero or negative. Policy parameters such as the property tax rate and period of delinquency are also shown to have impacts on abandonment: The greater the values of the two parameters, the longer the abandonment period. These results are meaningful to urban planners, as they can be used to design of municipal policies to mitigate or reverse urban decline.

The model can be extended in many directions. Two of the most promising include accommodation of negative spillovers and modeling a world of uncertainty. First, the model can be extended to endogenously accommodate the externalities due to abandonment. Since the commercial sector consists of many firms operating in a competitive market, there is no difficulty modeling their behavior when faced with externalities. If analytical solutions prove impossible, numerical simulation may be used. Second, the model also needs to be extended to deal with uncertainty, such as uncertainty about profits. This would explain why the prices of abandoned properties never fall to zero. Even if all sectors decline, property prices will remain positive as long as there is some probability of resurgence in the future.

Chapter 4: Tax Delinquency and Abandonment of Industrial and Commercial Properties

4.1 Introduction

Deindustrialization and the emergence of the knowledge-based economy have affected U.S. city regions for decades. Faced with this global shock, old industry regions and their central cities in particular, have suffered from an economic downturn and are struggling to reinvent themselves. As part of this process however, much of the capital employed by older industries loses its usefulness. When it is possible, and when there is demand, some properties are converted to new uses. When demand is not forthcoming, or when property prices drop too low, firms may abandon their properties. Abandonment is useful to a property owner, if gains from the non-payment of taxes exceed potential income from a property sale. For instance, in the Cleveland region, about 41 percent of industrial and commercial parcels have no building on them according to Northeast Ohio Community and Neighborhood Data for Organizing (NEO CANDO), a database system based on the Cuyahoga County Auditor's data.

Counties and cities track property delinquency rates for several reasons: as an indicator of the health of their economy, as an early warning signal of future defaults, and as sign of potential neighborhood decline. High rates of property abandonment are associated with high negative spillovers, foreshadow the loss of tax revenues and difficulties in funding services, and often suggest the need for actions that can nurture the economy back to health. There is therefore a considerable interest by local government in this information. Property tax records are the most timely records available, and they have the advantage of providing spatial details that can pinpoint potential problems at the neighborhood, street and parcel level. Because cadastral records provide much additional micro information on the type and use of properties, tax payment records can be linked to economic sectoral and regional information, which can help in shaping policies at a detailed locational level, whether it relates to policing or to infrastructure maintenance and rehabilitation.

Abandoned properties impose negative spillovers on their neighborhood, as they raise the risk of crime, arson and accidental fire, and cause other public nuisances (National Vacant Properties Campaign, 2005). Some abandoned properties are brownfields, which have aroused interest from policy agencies as well as from academia. But there are many other unattended industrial and commercial properties (ICPs) that have abandonment potential. Since they are not less vulnerable to economic downturn, their abandonment potential may be realized creating as many troubles in near future. In order to prevent and deal with the abandonment problems, it is important to identify which ICPs are likely to be abandoned in the new economy. Default property taxes for abandoned properties lead to a loss in tax revenue and make it more difficult for the local government to deal with the problems related to the abandonment (Community Research Partners & ReBuild Ohio, 2008).

Much of the literature focuses on residential and housing abandonment. As important however, are ICPs, as their delinquency rates are more directly related to the health of the local economy, and as they may lead delinquencies of residential properties and hence provide earlier evidence of problems to come. As a result, there is significant literature that explains tax delinquency and property abandonment rates, though as mentioned, this literature is limited to housing – and hence does not look at the relationship between abandonment and the overall economy.

This paper is motivated by a broad interest in local economies in transition, and in particular the process of de-industrialization and its impacts on local property markets and policy regimes that might mitigate economic adversity through redevelopment and new growth. Hence, this paper deals with industrial and commercial rather than residential properties. Unlike a residential property, an ICP is a factor of production and thus its use or abandonment is determined by a firm's investment decision, which is in turn directly influenced by the economy. Sectoral and regional differences in economic growth are reflected in the abandonment or use of different types of ICPs unlike in the case of housing abandonment. Some factors such as amenities that are important to residential properties may be made less account of. Such differences make it difficult to apply the models of housing abandonment as they are to the case of industrial abandonment.

Second, it differentiates between properties that are easily converted to other uses, and those that are not. As we have hypothesized, industrial properties often are designed to uniquely accommodate the needs of a particular manufacturing process, and because of this are often difficult and costly to convert to other uses. Hence, for firms in distress, or threatened by closure, it will be difficult to sell these properties. As a result one would expect that such firms would more often abandon properties than other firms with properties that are more easily converted. An affirmation of this result has significance beyond its immediate use in tax delinquency research, as it suggests to us a broader problem in urban revitalization. Specifically, a city with a large share of non-convertible, non-malleable legacy capital will have greater problems overcoming the effect of economic decline than otherwise similar cities without such capital.

This study estimates the likelihood of abandonment and the duration of tax delinquencies. As in the literature, a property is defined as being abandoned of it experiences 18 months or more of continuous tax delinquency (Arsen, 1992; White, 1986). We use data for the Cleveland city-region employing data on property characteristics and taxes obtained from a vast database system, Northeast Ohio Community and Neighborhood Data for Organizing (NEO CANDO).

The paper is organized as follows: Section 4.2 provides the theoretical background and literature review on property abandonment. Section 4.3 constructs the models and sets forth the methodology for the empirical analysis. Section 4.4 shows the estimation results and empirical findings. Finally, Section 4.5 discusses policy implications and the significances of the findings.

4.2 Theory and Literature on Property Abandonment

4.2.1 The problems of property abandonment

Here we explore the problems of abandoned property and operationally define property abandonment. We suggest that property tax arrearage be used as an early indicator of property abandonment, as it reflects a firm's disinvestment decision and data on it are readily available.

Abandoned properties give rise to many social costs and problems due to their negative externalities. They raise costs of municipal services, decrease tax revenue and property values in their neighborhoods, and decrease economic vitality. First, an abandoned property often becomes a hotbed of crime and a haunt for rodents, and it is exposed to the risk of arson or accidental fires. Dealing with these security and public health concerns imposes an additional burden on a municipality financially (Community Research Partners & ReBuild Ohio, 2008; National Vacant Properties Campaign, 2005). Second, abandonment of properties directly or indirectly leads to a loss of tax revenues for municipality. In the process of abandonment, the owner of an abandoned property usually stops paying property taxes, which are the major sources of local revenues. This leads to a direct loss in municipal revenues. An abandoned property also lower property values in its neighborhood and this also leads to a revenue loss due to the lower assessed values of properties(Community Research Partners & ReBuild Ohio, 2008; Griswold & Norris, 2007). Third, abandoned properties often prevent productive use of surrounding areas and impede economic activities in the region. Their physical deterioration and visual blight often impair quality of life for residents or consumers, and raises insurance premium in their neighborhoods (National Vacant Properties Campaign, 2005). To avoid such additional costs, firms avoid locating in the region and retailers leave the area, and it in turn leads to a decrease in economic vitality furthermore.

Property abandonment is not defined by a single action or event but by a process of continuous neglect and lack of care (Sternlieb, Burchell, Hughes, & James, 1974). This includes a neglect of owner responsibilities for functional, financial, and physical maintenance (Hillier, Culhane, Smith, & Tomlin, 2003). Functional neglect means that a property stops being used as intended, as suggested by the suspension of water and gas delivery and shuttered access. Financial neglect is indicated by arrears on debt and taxes, and by liens imposed on a property. Physical neglect is suggested by a lack of upkeep and maintenance, often leading to code violation. Property abandonment involves these three aspects of neglect over a prolonged period of time. Hence it is difficult to pinpoint the specific time when a property has been finally abandoned.

Regarding the financial aspect of abandonment, the property tax is not *in personam* but *in rem* and thus judicial judgment applies to the property rather than the property owner, in case tax obligations are not met. This offers the owner the option not to pay taxes when this is financially rewarding (Scafidi, Schill, Wachter, & Culhane, 1998). The owner of an ICP in particular takes advantage of this option to maximize (dis)investment profits. If the property value drops below future tax payments, she will choose not to pay taxes, i.e. property abandonment always involves tax delinquency. However, not all tax delinquency leads to property abandonment, as temporary problems with cash flow do not represent abandonment. One may need a cut-off point to distinguish between temporary and intended arrears and the literature suggests to take a continuous delinquency spell of 18 months or longer as an indicator to classify a property as abandoned (Arsen, 1992; White, 1986).

This is the also the definition adopted there, as data for a more complete determination of abandonment status based on all three aspects of neglect are not available in a timely fashion.

4.2.2 Determinants of property abandonment

Here we explore existing explanations on what factors determines property abandonment. Most of them come from the literature on housing or residential abandonment. We argue that for the case of ICP abandonment, special factors should be emphasized in addition to the traditional determinants used for residential abandonment.

Property abandonment occurs when demand is too low compared to supply to clear the property market. Various explanations are based on this approach and look into the sources of low demand or oversupply. The literature suggests that determinants of property abandonment be classified into four categories: agent characteristics, individual property characteristics, neighborhood characteristics, and policy variables. The first is related to the supply side and the second and the third are related to the demand side, while the last one constitutes the environment of the market.

First, agent characteristics refer to owner income, tenants’ race and income, institutional ownership, and absentee ownership. Property owners who are financially strapped cannot afford to fulfill their ownership responsibilities and thus abandon their property. Sternlieb et al. (1974) argues that an economically disadvantaged owner is likely to abandon her property. Institutional or absentee ownership also leads to a high rate of abandonment as these owners have little attachment to their properties beyond profit motivation. The relationship between the owner and tenants plays a role in this regard. Ball (2002) also argues that attitude and involvement of agents for property acquisition and development are vital. Many other studies use agent variables in explaining property abandonment (Arsen, 1992; Hillier et al., 2003; White, 1986).

Second, individual property characteristics refer to building price, building age, lot size, accessibility, and building condition. The underlying logic is that a property in poor condition or difficult to reuse or redevelop faces limited demand and thus is likely to be abandoned. Many empirical studies on housing abandonment show that these factors influence the probability of property abandonment. Hillier et al. (2003) finds that housing code violations are significant in explaining housing abandonment. Bell and Kelso (1986) shows that floor area ratio is negatively related to abandonment and that the number of units in the building is positively related to it. Bender (1979) finds that unit price is negatively related to abandonment and building age positively. Arsen (1992) also confirms that building age is significant. But Sternlieb et al. (1974) argue that physical characteristics are unimportant in contributing to abandonment relative to agent characteristics. Overall, property characteristics are important in explaining property abandonment, particularly when agent variables are not well known.

Third, neighborhood characteristics represent general attributes of the neighborhood as well as specific spillovers from individual properties. The former includes variables such as area density or share of parking lots, and the latter the adjacency of vacant, abandoned, or tax delinquent properties. Hillier et al. (2003) finds that adjacency to abandoned or demolished structures and adjacency to tax delinquent properties raise the probability of abandonment. Bell and Kelso (1986) also show that a large number of vacant buildings on contiguous parcels and many parking lots raise the abandonment rate while a large number of residential buildings in the neighborhood lower the rate.

Fourth, policy variables are related to property tax policies, including the assessment rate and grace period for tax delinquency. The literature explains that a high tax rate raises the financial burden of maintaining the ownership and thus raises the probability of abandonment. Arsen (1992) finds that a high assessment rate contributes to raising the abandonment rate and that the elasticity of abandonment with respect to assessment rate is between 2.0 and 3.7 depending on the type of residential buildings. White (1986) also shows that tax reduction and mitigation decrease the abandonment rate, having an elasticity between 2.53 and 2.93. Notable is her argument that a long grace period raises the abandonment rate, as property owners try to take full advantage of that period. Bender (1979) fails to confirm that the assessment rate is significantly related to abandonment when controlling for property price. However, the tax variables overall look important, as White's theoretical model is quite persuasive and Arsen's (1992) and White's (1986) estimation are more accurate than Bender's (1979).

Although all these factors are derived from studies on housing or residential abandonment, they can be applied with minor changes to the cases of ICP abandonment as well. In fact, there are only few recent studies on ICP abandonment, and these mainly describe the abandonment attributes via cross-tabulations rather than econometric analysis.[25] Ball's survey (2002) investigates physical characteristics such as building age, condition, size, and accessibility;

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[25] Munneke (1996) introduces a probit model to explain the redevelopment of ICPs. McGrath (2000) uses a Heckit model to explain the relationship between the risk of environmental contamination and redevelopment of industrial properties. But these two studies focus on redevelopment after normal transaction rather than abandonment.

agent factors such as attitude and involvement of agents; and policy factors such as subsidy. He examines the reuse potential of vacant industrial properties by comparing how these factors differ for vacant and reoccupied properties. Katyoka and Wyatt (2008) survey property characteristics of vacant industrial properties in terms of premise type, size, age, and location. The factors that these studies look into are not much different from the factors that are derived from housing abandonment.

There is an important difference between residential properties and ICPs. While residential properties are all used for the housing of their owners or tenants, ICPs are used as an input to produce *different* goods or services depending on their uses. This *heterogeneity of property use* should be considered in explaining abandonment of ICPs, as demands and investment plans for ICPs vary across different industries associated with different property uses. For instance, when the retail sector grows and the heavy manufacturing sector decline, industrial properties of manufacturers are more likely to be abandoned than commercial properties of retailers. In this vein, property use and the growth of industries associated with it play a crucial role in determining ICP abandonment. The following section deal with this issue using a simple model.

4.3 The Model and Methods

4.3.1 A model of ICP abandonment

Here we construct a simplified version of the abandonment model presented in Chapter 3. As discussed there, ICP abandonment is based on the disinvestment and investment plans of outgoing and incoming firms respectively. The model suggests that abandonment occurs if the outgoing firm, faced with a declining demand, stops maintenance and property tax payments before the incoming firm's demand grows sufficiently to pay the property price plus the cost of converting the property to another use. The property market, of course, tries to clear the market by lowering the price of the property, but this mechanism does not work in the case of abandonment, as temporary abandonment is optimal for both firms. Note here that the incoming and outgoing firms can be the same firm only if they operate different businesses and expect different growth rates at different time periods. For clearer understanding, we illustrate the model assuming the firms are different from each other.

Consider first the outgoing firm. Suppose that the firm is monopolistic in its good market and is faced with a diminishing demand. Then the firm disinvests capital and reduces its labor employment, and thus its operating profit also declines. It is not difficult to show that the firm's labor employment and net profit decline at the rate of demand. Let μ_1 denote the declining rate of demand and labor employment. Then the firm's operating profit, ϕ^{out} before paying the fixed maintenance costs declines at the same rate:

$$\phi^{out} = \phi_0^{out} e^{-\mu_1 t} \tag{4.1}$$

where ϕ_0^{out} is the initial profit. Suppose that the firm incurs a fixed maintenance cost τ such as property taxes to keep its ownership. Then the firm will operate only until its net profit becomes equal to the fixed cost. In other words, there is no reason for the firm to operate beyond the point when costs start to exceed net profits. That time is obtained by equating (4.1) with the fixed cost τ. The result is as follows:

$$t_d = \frac{1}{\mu_1} \log \frac{\phi_0^{out}}{\tau} \tag{4.2}$$

From this point, the firm will neglect its ownership responsibilities including paying taxes. That is, the time in (4.2) is the starting point of tax delinquency.[26]

Consider next the incoming firm. Suppose that the firm is faced with growing demand as opposed to the outgoing firm, and that its operating profit grows at the rate of μ_2. That is,

$$\phi^{in} = \phi_0^{in} e^{\mu_2 t}$$

where ϕ_0^{in} is the initial profit. Suppose that the current demand is not high enough to pay entry costs including the property price plus the cost of converting the property. Then the firm must choose the optimal entry time to maximize its expected profit. Too early an entry may result in negative profits until demand is high enough to cover the interest of the entry costs, and too late an entry may waste potential profits. If the firm enters at time t_e. The firm's discounted value at time zero of operating in an infinite time horizon is derived by computing the present value of the sum of operating profits net of initial entry costs. Formally, this is[27]

$$V_0 = \frac{\phi_0^{in}}{r - \mu_2} e^{(\mu_2 - r)t_e} - (pL + S)e^{-rt_e} \tag{4.3}$$

where *p*, *L*, and *S* are property unit price, property size, and the conversion cost. The first term is the discounted value of all the operating profits, and the second term is the present value of the fixed entry costs. The firm's optimal entry time t_e^* is derived by equating to zero the derivative of (4.3) with respect to t_e. The result is

$$t_e^* = \frac{1}{\mu_2} \log \frac{pL + S}{\phi_0^{in}/r} \tag{4.4}$$

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[26] For simplicity, the grace period is assumed to be zero in this model. If the grace period *d* is not zero, then the starting point will be advanced by $\left(1 + \frac{r}{\mu_1}\right) d$, where *r* is the interest rate. For details of this problem, see White (1986).

[27] $\mu_2 < r$ is assumed to make the case realistic and simple. If $\mu_2 > r$, then the value becomes infinite, which is unrealistic.

Tax delinquency occurs if this optimal entry time is later than the starting point of the outgoing firm shown in (4.2). The latent tax delinquency duration (TDD) tdd^* is then the time between the two time points:

$$tdd^* = t_e^* - t_d = \frac{1}{\mu_2}\log\frac{pL+S}{\phi_0^{in}/r} - \frac{1}{\mu_1}\log\frac{\phi_0^{out}}{\tau}$$

Note that a negative value is not ruled out for T_{del}^*, while actually observed values are only positive. That is the reason that the modification 'latent' is being used; the deference between 'actual' and 'latent' TDDs will be discussed in Section 4.3.2.1. The denominator of the antilogarithm in the first term can be interpreted as the myopic price[28] that would be created if the property were used for the incoming sector, as it represents the value of the firm in an infinite horizon if the profit stays at the same level as the initial one. The numerator of the antilogarithm in the second term can also be interpreted in the same way. That is, the initial operating profit equals the fixed maintenance costs plus the interest of the myopic property price. Formally,

$$\phi_0^{out} = r\bar{p}_1 L + \tau$$

$$\frac{\phi_0^{in}}{r} = \bar{p}_2 L$$

where by $\bar{p}_1$ and $\bar{p}_2$ are the myopic unit prices that would be formed if the property were used for the outgoing sector and the incoming sector, respectively. Hence the latent TDD can be rewritten as

$$tdd^* = \frac{1}{\mu_2}\log\frac{p+S/L}{\bar{p}_2} - \frac{1}{\mu_1}\log\left(\frac{r\bar{p}_1}{\tau/L}+1\right) \tag{4.5}$$

[28] Note that the equilibrium price is never observed before the transfer is actually realized, while myopic prices are sometimes observed in the form of tax collector's evaluation.

Equation (4.5) implies that the tax delinquency spell is determined by the growth rates of the outgoing and incoming sectors, the unit conversion cost, the two myopic property prices, the actual sales price of the property, and the fixed maintenance cost per a square foot of property such as property tax rates. The spell becomes longer, as

i) the decline rate of the outgoing sector (μ_1) becomes larger;
ii) the growth rate of the incoming sector (μ_2) becomes smaller;
iii) the unit conversion cost (S/L) becomes larger;
iv) the two myopic prices ($\bar{p}_1$ and $\bar{p}_2$) become smaller;
v) the equilibrium sales price (p) becomes larger, and
vi) the fixed maintenance cost per a square foot of property (τ/L) become larger.

Of these variables, i), ii) and iii) are never considered in the residential property abandonment, but they should be certainly taken into account in the case of ICPs. Note that the delinquency spell shortens with the two myopic prices, while it lengthens with the actual sales price. Also note that the equilibrium sales price is determined endogenously by the interaction of agents just as with the entry time, and thus it is not an exogenous variable but an endogenous variable that can be reduced to a function of the other exogenous variables. Hence it should not be included in the reduced form of equation for TDD. On the contrary, the myopic prices are purely exogenous and thus they should be included in the reduced form.

We define a binary response variable *abnd*, taking on the values zero and one, which indicate whether or not an abandonment event of an ICP has occurred. Based on the operational definition of an abandonment event in Section 4.2.1, this binary response can be written as an indicator function of the above variables. Formally,

$$abnd = 1[tdd^* \geq 18\, months] \tag{4.6}$$

where $1[\cdot]$ is the indicator function that returns unity whenever the statement in brackets is true, and zero otherwise. Hence a property is more likely to be abandoned, the longer the tax delinquency spell becomes. In other words, the conditions of i) through vi) raises the probability of abandonment of a property.

4.3.2 Empirical methods

Here we construct two empirical models, one for tax delinquency duration (TDD) and the other for probability of abandonment, based on the theoretical model in Section 4.3.1 and present econometrical methods to estimate the models. For the first model, we use a Tobit model because the length of a tax delinquency spell is a corner solution outcome and because there is the problem of data censoring for uncompleted spells. For the second model, we use a probit/logit model because abandonment is a binary response variable.

4.3.2.1 Model for tax delinquency duration (TDD)

Consider first the model for TDD. From Equation (4.5), we can write a reduced form equation for TDD.

$$tdd^* = T(\mu_1, \mu_2, \bar{p}_1, \bar{p}_2, S/L\,, \tau/L\,, r) \tag{4.7}$$

where $T(\cdot)$ is a function of the exogenous variables. Since some of the exogenous variables are unobservable or difficult to measure accurately, however, they need to be proxied by observables.

In this study, we do not have exact information on the outgoing and incoming firms but only roughly know the uses of properties. For instance, we know that a property is used for a cafeteria restaurant but do not know which brand is now being operated on it and which brand will take it over, much less the growth rates μ_1 and μ_2. Since a rough property use may cover a spectrum of firms within the industries that are likely to be associated with the use, we use the average growth rate of those industries. Let the average be denoted by μ. Then the two growth rates may be expressed as $\mu_1 = \mu + \epsilon_1$ and $\mu_2 = \mu + \epsilon_2$, where ϵ_1 and ϵ_2 are unobservable deviations satisfying $\epsilon_1 < \epsilon_2$ for the outgoing and incoming firms. Some property variables discussed in Section 4.2.2 may explain the unobservable deviations, but those cannot substitute for these exactly.

We also cannot observe the two myopic prices $\bar{p}_1$ and $\bar{p}_2$. The only information likely to be related to these variables is the property value evaluated by the local government. The tax collector evaluates a property on a regular basis by observing the market prices of similar properties without knowledge on the growth rates. Thus its evaluation roughly reflects the myopic price of a property. Let the evaluated value be denoted by $\bar{p}$. Then the two myopic prices may be expressed as $\bar{p}_1 = \bar{p} + \delta_1$ and $\bar{p}_2 = \bar{p} + \delta_2$, where δ_1 and δ_2 are unobservable deviations for the outgoing and incoming firms. Again, some observable variables may explain parts of the deviations. The unit conversion cost is also unknown, and thus it should be proxied by other observables.

These observation limits makes us estimate the model in (4.7) using a stochastic model where some variables are replaced by observable proxies. For the moment, consider a latent outcome for TDD that would be obtained if not for any constraint and any data censoring problem, and let tdd^* denote the latent outcome. Then a stochastic version is written as

$$\begin{gathered} tdd^* = \gamma_1 \mu + \gamma_2 \log \bar{p} + \gamma_3 trate + \mathbf{z}\boldsymbol{\pi} + u \\ u \mid (\mu, \bar{p}, trate, \mathbf{z}) \sim \text{Normal}(0, \sigma^2) \end{gathered} \tag{4.8}$$

where *trate* is the property tax rate, $\mathbf{z}$ is a vector of exogenous variables discussed in Section 4.2.2, $\boldsymbol{\gamma} = (\gamma_1, \gamma_2, \gamma_3)$ and $\boldsymbol{\pi}$ are vectors of parameters, u is the error term and σ is the standard error of the error term.

This model has two problems, however, that is, the corner solution outcome problem and the data censoring problem. First, there are many corner solution outcomes in actual tax delinquency, which is zero, because there is a constraint that TDD cannot be smaller than zero.

Second, there are many records with TDD censored simply because they are uncompleted by the times of observation. Ignoring these two problems leads to a biased estimation of the parameters. In order to deal with these problems, we introduce a Tobit model following Tobin (1958). The observed TDD is modeled as

$$tdd = \begin{cases} 0 & \text{if } tdd^* \leq 0 \\ tdd^* & \text{if } 0 < tdd^* < b \\ b & \text{if } tdd^* \geq b \end{cases} \tag{4.9}$$

where tdd^* is modeled in the same way as in (4.8) and b is the variable specifying upper bound for each observation. In the model, only the latent TDDs falling into the region (0, b) are not censored. If they are negative, then they are forced to be zero by the non-negativity constraint. If they are greater than the upper bounds, then they are censored into the bounds.

The estimation of the model is done using the method of maximum likelihood estimation (MLE) as usual. The log-likelihood of the doubly censored model in (4.9) for observation i is written as

$$l_i(\boldsymbol{\beta}, \sigma) = 1[y_i = 0] \log\left[\Phi\left(-\frac{\boldsymbol{x}_i\boldsymbol{\beta}}{\sigma}\right)\right] + 1[y_i = b_i] \log\left[\Phi\left(\frac{\boldsymbol{x}_i\boldsymbol{\beta} - b_i}{\sigma}\right)\right]$$

$$+ 1[0 < y_i < b_i] \log\left[\frac{1}{\sigma}\phi\left(\frac{y_i - \mathbf{x}_i\boldsymbol{\beta}}{\sigma}\right)\right]$$

where $\mathbf{x}$ and $\boldsymbol{\beta}$ denote the vectors of all the exogenous variables and of the parameters of the linear model; and Φ and ϕ denote the normal standard cumulative density function (cdf) and the standard normal probability density function (pdf).

For corner solution problems like the model in this paper, the interpretation of the model parameters is not straightforward since the model is not a linear model. One should calculate two types of marginal effects of explanatory variables, unconditional marginal effect and conditional marginal effect. Unconditional marginal effect represents the partial effect on the unconditional expected value, $\mathrm{E}(y|\mathbf{x})$, while conditional marginal effect represents that on the expected value conditional on positivity of the dependent variable, $\mathrm{E}(y|\mathbf{x}, y > 0)$. Since they depend on the values of explanatory variables, we evaluate them at the mean values. The two marginal effects for a continuous variable are calculated as follows (Wooldridge, 2002):

$$\frac{\partial \mathrm{E}(y|\mathbf{x})}{\partial x_j} = \Phi\left(\frac{\mathbf{x}\boldsymbol{\beta}}{\sigma}\right)\beta_j \tag{4.10}$$

$$\frac{\partial \mathrm{E}(y|\mathbf{x}, y > 0)}{\partial x_j} = \beta_j \left\{1 - \lambda\left(\frac{\mathbf{x}\boldsymbol{\beta}}{\sigma}\right)\left[\frac{\mathbf{x}\boldsymbol{\beta}}{\sigma} + \lambda\left(\frac{\mathbf{x}\boldsymbol{\beta}}{\sigma}\right)\right]\right\} \tag{4.11}$$

where $\lambda(\cdot)$ is the inverse Mills ratio and it is defined as $\lambda(c) = \phi(c)/\Phi(c)$ for any quantity c. For a dummy variable, the two types of marginal effects are calculated as the differences of the expected values when the variable changes from zero to one, holding all the other variables fixed at the mean values. If x_k is a binary variable, then the unconditional marginal effect of changing x_k from zero to one is

$$\mathrm{E}(y|\bar{x}_1, \bar{x}_2, \cdots\cdots, \bar{x}_{k-1}, 1) - \mathrm{E}(y|\bar{x}_1, \bar{x}_2, \cdots\cdots, \bar{x}_{k-1}, 0) \tag{4.12}$$

where $\mathrm{E}(y|\bar{\mathbf{x}}) = \bar{\mathbf{x}}\boldsymbol{\beta}\Phi\left(\frac{\bar{\mathbf{x}}\boldsymbol{\beta}}{\sigma}\right) + \sigma\phi\left(\frac{\bar{\mathbf{x}}\boldsymbol{\beta}}{\sigma}\right)$. The conditional marginal effect is then

$$\mathrm{E}(y|\bar{x}_1, \bar{x}_2, \cdots\cdots, \bar{x}_{k-1}, 1, y > 0) - \mathrm{E}(y|\bar{x}_1, \bar{x}_2, \cdots\cdots, \bar{x}_{k-1}, 0, y > 0) \tag{4.13}$$

where $\mathrm{E}(y|\bar{\mathbf{x}}, y > 0) = \bar{\mathbf{x}}\boldsymbol{\beta} + \sigma\lambda\left(\frac{\bar{\mathbf{x}}\boldsymbol{\beta}}{\sigma}\right)$. All the other binary variables are evaluated to be unity in (4.12) and (4.13), since the mean values are not much meaningful for binary variables.

4.3.2.2 Model for abandonment probability

Consider next the model for the probability of abandonment of ICPs. Using Equations (4.6) and (4.8), one can derive the probability model as follows:

$$\begin{aligned} \mathrm{P}(abnd = 1|\mathbf{x}) &= \mathrm{P}(tdd^* \geq 18|\mathbf{x}) = \mathrm{P}(u \geq 18 - \mathbf{x}\boldsymbol{\beta}|\mathbf{x}) \\ &= 1 - F(18 - \mathbf{x}\boldsymbol{\beta}) = F(\mathbf{x}\boldsymbol{\beta} - 18) \end{aligned} \tag{4.14}$$

where F is the cdf of Normal $(0, \sigma^2)$. The marginal effect of a continuous explanatory variable is then calculated as

$$\frac{\partial \mathrm{P}(abnd = 1|\mathbf{x})}{\partial x_j} = f\left(\frac{\mathbf{x\beta} - 18}{\sigma}\right)\frac{\beta_j}{\sigma} \tag{4.15}$$

where $f(z) = dF(z)/dz$. For a dummy variable, the marginal effect is calculated as the difference of the probability when the variable changes from zero to one, holding all other variables fixed at the mean values. If x_k is a binary variable, then the marginal effect of changing x_k from zero to one is

$$F(\bar{x}_1, \bar{x}_2, \cdots\cdots, \bar{x}_{k-1}, 1) - F(\bar{x}_1, \bar{x}_2, \cdots\cdots, \bar{x}_{k-1}, 0) \tag{4.16}$$

All the parameters in Equation (4.14) are already estimated for the TDD model defined by (4.8) and (4.9). Therefore, one may rely only on the results of the previous model to derive the marginal effect of each variable on the abandonment probability.

Alternatively, we can construct a binary response model separately, using the probability of abandonment as the dependent variable. This alternative way is meaningful for the comparison purpose to check whether the estimates are stable across different methods of modeling. It is also particularly important, since the effects of explanatory variables may be different in explaining TDD in general from in explaining it around the limit for abandonment, that is, 18 months of duration.

In a binary response model, the abandonment probability is written as

$$\begin{aligned} &P(abnd = 1|\, \mu, \bar{p}, trate, \mathbf{z}) \\ &\qquad = G(\tilde{\gamma}_1\mu + \tilde{\gamma}_2 \log \bar{p} + \tilde{\gamma}_3 trate + \mathbf{z}\tilde{\boldsymbol{\pi}}) \end{aligned} \tag{4.17}$$

where $\tilde{\boldsymbol{\gamma}} = (\tilde{\gamma}_1, \tilde{\gamma}_2, \tilde{\gamma}_3)$ and $\tilde{\boldsymbol{\pi}}$ are vectors of parameters, and $G(\cdot)$ is a cdf. We introduce two types of cdf: the standard normal cdf for a probit model and the standard logistic distribution for a logit model. In other words, in the probit model, $G(\cdot)$ is written as

$$G(z) = \Phi(z) \equiv \int_{-\infty}^{z} \phi(v)dv$$

In the Logit model, $G(\cdot)$ is written as

$$G(z) = \Lambda(\mathrm{z}) \equiv \frac{\exp(z)}{1 + \exp(z)}$$

The estimation of the model is done with MLE using the above probability density functions. The interpretation of the model parameters in the binary models also requires some care, as the coefficients of the model are not the marginal effects. Thus one should separately calculate the marginal effects of explanatory variables. For a continuous variable x_j , it is computed as follows(Wooldridge, 2002):

$$\frac{\partial \mathrm{P}(abnd = 1|\mathbf{x})}{\partial x_j} = g(\mathbf{x\beta})\beta_j \tag{4.18}$$

where $g(z) = dG(z)/dz$. Since it depends on the values of explanatory variables, we evaluate it at the mean values. For a dummy variable, the marginal effect is calculated as the difference of the cdf when the variable changes from zero to one, holding all other variables fixed at the mean values. If x_k is a binary variable, then the marginal effect of changing x_k from zero to one is

$$G(\bar{x}_1, \bar{x}_2, \cdots\cdots, \bar{x}_{k-1}, 1) - G(\bar{x}_1, \bar{x}_2, \cdots\cdots, \bar{x}_{k-1}, 0) \tag{4.19}$$

where all the other binary variables are again evaluated to be unity.

4.4 Empirical Study: the Cleveland Region

4.4.1 Data and variables

Here we introduce the subject of our empirical study, data sources and variables of the models. The processes of extracting TDD from the annual tax data and matching property uses to industries are explained. We also present how key variables such as growth rates are measured.

We apply our empirical models to individual ICPs in Cuyahoga County with its county seat located in a representative old industrial city, Cleveland of Ohio. The study population consists of all the properties whose land uses have ever been commercial and industrial during tax years 1994 through 2007, except for commercial housing, public utilities and golf courses. The selected property use types are listed in Appendix D. Observations of a tax delinquency spell are limited to the properties that have tax delinquency starting between January 1995 and January 2009, but there is no limit to the ending points of a tax delinquency. There have been 35,994 parcels of this category between tax years 1994 and 2007, and of these 11,252 parcels (31.3%) have ever been in property tax arrears once or more. 6,329 parcels (17.6%) have ever been abandoned, that is, tax delinquent for 18 months or longer.

Data on property characteristics and transactions are obtained from Northeast Ohio Community and Neighborhood Data for Organizing (NEO CANDO), a social and economic data system of the Center on Urban Poverty and Community Development at Case Western Reserve University. The system regularly collects, integrates, and updates property data originating from the Cuyahoga County Auditor and Recorder. From this data source, we get information on delinquent property taxes, building condition, evaluated property price, property (land) use, and sales history.

Spatial data of properties are obtained from the Northern Ohio Data and Information Service (NODIS). They collect information on parcel location and size originally from the Cuyahoga County Auditor, and map the information using GIS. We use the spatial data as of January, 2008 to measure the location and size of each parcel. Some property size data may be missing and differ from that at the time of tax delinquency because of the annexation of parcels, but this is regarded a nonsystematic error. Spatial data on interstate highways are obtained from the Census 2000 TIGER/Line® data through the ESRI website. From these spatial data sources, we obtain information on the distance to the CBD,[29] distance to the nearest Interstate Highway, and property size.

It is of help in understanding the data to explain how to extract TDD from the database system, as it is not obvious due to missing tax data for some years in 1990s. NEO CANDO includes annual tax data for all properties in Cuyahoga County for tax years 1990, 1994, 1997, and 2000s. The tax data include the evaluated market price and delinquent taxes for a property. Data on TDD are obtained by integrating these annual data of delinquent taxes into a single table.[30] An event where delinquent taxes continue to grow at annual tax rate plus penalty and interest is counted as one tax delinquency spell. The duration is calculated as the interval between the starting point and ending point. The only challenge is to figure out the starting and ending points. For properties with tax delinquency starting in 2000s, it is not difficult to extract this information. If a property is tax delinquent this tax year and gets out of it during the next tax year, then the ending point is identified by the first due date of the next tax year's payment. The starting point is estimated by comparing the tax due with the amount of delinquent taxes for the first tax year of a delinquency spell. If it is about a half of the due, then the starting point is identified with the second due date. If it is almost the same as the full due, then the starting point is identified with the first due date. For the properties with tax delinquency starting in the 1990s, however, the starting points are not obvious and the ending points may also be censored if a spell does not last until 2000. The starting point is again estimated by comparing the sum of tax dues for the previous years with the amount of delinquent taxes for the recorded first tax year of a

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[29] Distance to the CBD is calculated from a parcel to the Key Tower, which is a landmark in Cleveland's downtown.

[30] This idea is similar to the extraction of vacancy duration from annual vacancy data by Myers and Wyatt (2004). But they do not estimate the starting point if a spell is censored in the left, while we do using the data of delinquent tax amounts.

delinquency spell. The starting point is traced back in this way, but it should not go back to the first previous tax year. For instance, if a property has no delinquent tax in 1990 but has 1994, then the starting point of its tax delinquency should be between 1990 and 1994. The censored ending points are modeled in the Tobit model in the form of modified likelihood function as shown in Section 4.3.2.1.

Other key variables are related to the decline/growth rate of an outgoing firm/incoming firm on an ICP. Due to lack of information as discussed earlier, we substitute two types of growth rates for each firm's growth rate: One is the industrial growth rate (*empgrw*), and the other is the regional growth rate (*zpempgr*). The underlying logic is that if the industry or the region that a firm belongs to grows, then the firm is also likely to grow. First, look at how to get data for the growth rate of the industry associated with a property. The challenge is to match industries to a property. NEO CANDO has information on the land use of each parcel for each tax year. There are about 150 classes of land uses for ICPs, for instance loose material and storage yard. The level of detail of this classification is not consistent with that of traditional industry classification codes such as SIC. Therefore the matched levels of industry classification codes vary across land uses of ICPs. Appendix D shows SIC codes, NAICS 1997 and NAICS 2002 codes corresponding to the land use codes of ICPs. Once the matching is done, the corresponding growth rate is computed using the employment data of County Business Patterns (CBP) for Cuyahoga County; recall that demand and net profit grow at the same rate as employment growth rate. The industrial employment growth rate is calculated for the last three years before the ending year of tax delinquency. Next, the regional growth rate is calculated for the zip code tabulation area (ZCTA) that a property is located in. We compute the growth rate of total employment for the last four years before the ending year of tax delinquency.

Other variables include neighborhood vitality, property tax rate, conversion indicators and trend. First, neighborhood vitality (*deltract*) is measured by delinquent taxes per $ 1,000 market value of properties at the census tract level. The ratios for the last three or four years prior to the starting year of a tax delinquency spell is averaged to obtain a neighborhood vitality index. Second, property tax rate (*trate*) data comes from the website of Ohio Department of Taxation. Cuyahoga County has 58 cities and villages with different property tax rates. We use the rate of the place where a property locates. Third, we use four variables for the conversion costs, as the costs themselves are not known: Three indicators for land use change, ownership change, and building existence; and a building condition variable. A change in land use or ownership for a property very likely requires more conversion than otherwise. The existence of buildings sometimes obstructs the reuse of a lot when demolition is required for another use. Building condition obviously impacts the conversion cost as well. These proxies for the conversion cost are defined as follows: If a property has land use changed within two years after the ending year of tax delinquency, the land use change indicator (*convrt*) has unity and zero otherwise. If a property is sold in between six months before and after the ending point, the ownership change indicator (*sale*) is coded to unity and zero otherwise. If a property has any buildings, then the building indicator (*bldg*) has unity and zero otherwise. Building condition (*bldgcond*) is measured in ordinal scale as follows: No building (0), unsound value (1), sound value (2), very poor (3), poor (4), fair (5), average (6), good (7), very good (8), and excellent (9). Lastly, trend (*trend*) is a variable for controlling for time trend of tax delinquency, as tax delinquency may be influenced by business cycle. The trend variable is computed as the fraction of tax delinquent ICPs in all ICPs in the whole county in the starting year of a tax delinquency spell. The variables and data sources are summarized in Table 4.1 and the descriptive statistics for the variables are reported in Appendix F.

Variables	Definition	Sources
tdd	Property tax delinquency duration in months.	NEO CANDO
abnd	1 if tax delinquency duration is 18 months or longer; 0 otherwise.	NEO CANDO
trend	The number of tax delinquent ICPs as a percentage of total number of ICPs in Cuyahoga County in the starting year of tax delinquency.	NEO CANDO
logsfval	The natural logarithm of the price, as measured in 2000 dollars, per square foot of an ICP evaluated by the county auditor.	NEO CANDO BEA*
bldg	1 if a parcel has a building or more; 0 otherwise.	NEO CANDO
bldgcond	Building condition coded from 'no building' (0) to 'excellent' (9).	NEO CANDO
zpempgr	Total employment growth rate at the ZCTA level over the four years before the ending year of tax delinquency.	County Business Patterns & CTPP 1990**
empgrw	Average employment growth rate of industries corresponding to a land use at the County level over the three years before the ending year of tax delinquency.	County Business Patterns
deltract	Delinquent taxes per $ 1,000 market value of all properties at the census tract level.	NEO CANDO
convrt	1 if the land use of a parcel is changed within two years of the ending year of tax delinquency; 0 otherwise.	NEO CANDO
dis_cbd	Distance to the Key Tower in mile.	NODIS
east	1 if an ICP is in the east of the Cuyahoga River; 0 otherwise.	NODIS
east_discbd	Equal to *dis_cbd* multiplied by *east*.	NODIS
cbdsq	The square of *dis_cbd*.	NODIS
ecbdsq	The square of *east_discbd*.	NODIS
dis_ihw	Distance to the nearest Interstate Highway in mile.	NODIS
east_disihw	Equal to *dis_ihw* multiplied by *east*.	NODIS
hwsq	The square of *dis_ihw*.	NODIS

Continued

Table 4.1: Variable Definitions and Data Sources

Table 4.1 Continued

indust	1 if the land use of a parcel is categorized to industry; 0 otherwise.	NEO CANDO
txrate	Net property tax rate in millage.	Ohio Department of Taxation
sale	1 if an ICP is sold within two years of the ending year of tax delinquency; 0 otherwise.	NEO CANDO
acre	Area of a parcel in acre.	NODIS

*BEA: Implicit price deflators of GDP as revised by Bureau of Economic Analysis on June 25, 2009 is being used to convert property prices into dollars of 2000.

**CTPP 1990: Census Transportation Planning Package 1990. It is being used to obtain the information on employment in 1990 at the ZCTA level, as CBP reports that information from 1994.

4.4.2 Empirical Findings

Here we present the estimation results of the models and the marginal effects of variables on tax delinquency duration (TDD) and the abandonment probability. The predictions of the theoretical model in Section 4.3.1 are verified.

4.4.2.1 Tax delinquency duration (TDD) model

The model for tax delinquency duration is estimated using data of the whole population. The population, however, includes multiple-spell data for some parcels, as the study period is long relative to the average delinquency duration. 4,344 parcels, that is, 12.1 percent of the population have indeed experienced more than one tax delinquency spell during the period in question. Multiple-spell data may lead to the problem of clustered data. To avoid the problem, we randomly choose only one spell for each parcel. The population also includes many zero duration data as mentioned earlier. For the parcels without delinquent taxes, one cannot obviously determine the starting and ending points of a delinquency spell, which is problematic because some variables such as growth rate and tax rate are time variant. To solve this problem, we again randomly choose the starting point during the time in question, and then the ending point has to be the same as the starting point by definition of no delinquency. Excluding records with missing data, we use data for 28,928 parcels.

The full results of maximum likelihood estimation (MLE) are reported in Table 4.2. The table shows the coefficient estimates for explanatory variables with inference statistics. It also shows the two types of marginal effects for explanatory variables separately, which are calculated using (4.10) – (4.13) . The unconditional marginal effect is useful to predict the effect when we do not know whether a property is in tax arrears or not, while the conditional marginal effect is useful when we know that a property is in tax arrears.

Dependent Variable: *tdd*						
Independent Variable	Estimate	Std. Err.	t Value	Pr > |t|	Unconditional Marginal Effect	Conditional Marginal Effect
trend	3.486817	0.102502	34.02	<.0001	1.69066	1.23850
logsfval	-2.946552	0.381623	-7.72	<.0001	-1.42870	-1.04660
bldg	21.051311	1.869784	11.26	<.0001	7.88380	6.31888
bldgcond	-3.484165	0.333090	-10.46	<.0001	-1.68937	-1.23755
zpempgr	-6.273501	1.692490	-3.71	0.0002	-3.04184	-2.22831
empgrw	-6.913827	0.995505	-6.95	<.0001	-3.35232	-2.45575
deltract	0.150216	0.012930	11.62	<.0001	0.07284	0.05336
convrt	7.735374	0.894471	8.65	<.0001	3.42819	2.58016
dis_cbd	-2.477587	0.327866	-7.56	<.0001	-1.20131	-0.88002
east_discbd	3.273759	0.323769	10.11	<.0001	1.58735	1.16282
cbdsq	0.087371	0.020987	4.16	<.0001	0.04236	0.03103
ecbdsq	-0.255879	0.025167	-10.17	<.0001	-0.12407	-0.09089
dis_ihw	8.840778	1.234225	7.16	<.0001	4.28665	3.14019
east_disihw	4.025233	0.977857	4.12	<.0001	1.95172	1.42974
hwsq	-3.734881	0.382990	-9.75	<.0001	-1.81094	-1.32661
indust	-12.222023	0.766265	-15.95	<.0001	-6.73226	-4.80109
txrate	0.087067	0.029665	2.94	0.0033	0.04222	0.03093
sale	10.815045	1.420882	7.61	<.0001	4.61640	3.51927
acre	0.106817	0.040568	2.63	0.0085	0.05179	0.03794
intercept	-57.112534	3.115667	-18.33	<.0001		
Number of observations		28,928				
Log-likelihood value		-44,670				
Pseudo *R*-squared		. 2072				
$\hat{\sigma}$	36.751998	0.371726	98.87	<.0001		

Table 4.2: Full Regression Results for TDD

The performance of the model is overall good. The *t*-values and *p*-values are all so good that the included explanatory variables are all significant at the 1 percent level, and most of them are significant even at the 0.1 percent level as well. The measures of goodness-of-fit of the model also suggest that the model's explanatory power is good. The reported pseudo R-squared is calculated following McKelvey and Zavoina (1975), as their measure is known to be the best for Tobit models (Veall & Zimmermann, 1994). The good performance of the model implies that the estimation results are reliable. Moreover, all the signs of the coefficients are reasonable, in light of the theory in Section 4.3.1. Let's look at the effect on TDD of each variable in detail below.

First, fast growth or at least slow decline of an industry and a region reduces the TDD, if ever, of an ICP belonging to the industry and region. Consider first the impact of industrial growth (*empgrw*). Everything else being equal, a 10 percentage point higher growth rate (or slower decline) in a sector over three years reduces TDD by about 10 days on average for all ICPs. For ICPs already in tax arrears, it reduces the duration by about 7.4 days. Consider next the impact of regional growth (*zpempgr*). Everything else being equal, a 10 percentage point higher growth rate or slower decline in a region over four years reduces TDD by about 9.1 days for all ICPs, and by 6.7 days for ICPs in tax arrears.

Second, high conversion costs of an ICP lead to a longer tax delinquency spell. Conversion costs are measured by several variables: building condition, land use change, ownership change, and parcel size. Consider first the effect of building condition (*bldgcond*). Everything else being equal, a one level better building condition reduces TDD by about 51 days for all ICPs and by about 37 days for ICPs already in tax arrears on average. However, the existence of a building (*bldg*) itself will lengthen the duration, as it should be demolished and this incurs additional costs particularly when its condition is not good. The model suggests that the existence of a building lengthens the tax delinquency spell by about 7.9 months for all ICPs and by 6.3 months for ICPs in tax arrears. Synthesizing the two results yields the conclusion that a building in poor condition, specifically, worse than fair, i.e. level (5), does not help to reduce TDD. On the other hand, a building in good condition has the net effect of reducing the duration. Consider two cases of tax delinquency, where one parcel has a building at level (9), i.e. excellent, and the other has a building at level (1), i.e. unsound. The net effect of the building is a 4.8 month decrease in TDD for the first case, while the net effect is a 5.1 month increase in the duration for the second case.

Consider next the effect of a land use change (*convrt*). A future land use change indicates that the current use is in low demand, and that the new firm should bear higher conversion costs than a conversion within the same land use. For instance, a conversion from an industrial property to a commercial one is likely to incur higher costs than the conversion from a commercial property to another commercial one. Everything else being equal, a land use change leads to a 3.4 month increase in TDD for all ICPs and 2.5 months increase for ICPs already in tax arrears. The effect of ownership change (*sale*) can be interpreted in the same way as a land use change. Ownership change is likely to incur higher conversion costs than otherwise, as the change may involve a larger conversion. The estimation results suggest that ownership change lengthens TDD by 4.6 months for all ICPs, and 3.5 months for tax delinquent ICPs.

Consider finally the effect of parcel size (*acre*). It influences TDD through conversion costs. If property conversion is carried out with constant returns to scale technologies, the acreage will not influence unit conversion costs. If there are decreasing returns to scale, then the conversion cost per square foot increases with acreage and hence the TDD becomes longer. The model estimation results show that there are indeed scale diseconomies, though the effect is very small. A one acre increase in the parcel size leads only to 1.5 day increase in TDD for all ICPs and only to 1.1 day increase for tax delinquent ICPs. These results suggest that the parcel size effect is almost negligible.

Third, a high tax rate (*txrate*) leads to a longer tax delinquency spell. As explained by the theory, a high tax rate means a high maintenance cost for a firm, and hence the firm stops paying taxes earlier. The estimation results suggest that a 10 millage point increase in tax rate leads to a 12.6 day increase in TDD for all ICPs, and a 9.2 day increase for tax delinquent ICPs. Notable is that the effect of is not so large, even though the results confirm the theoretical prediction.

Fourth, an ICP with a low myopic price (*logsfval*) is likely to be in tax arrears for a long time. Since the myopic price of a property reflects the current net profit of the firm, a high price implies that the firm likely will delay its tax default. According to the estimation results, doubling the price leads to a 43 days shorter TDD for all ICPs, and about a one month shorter duration for tax delinquent ICPs. These results imply that a low price is a good signal for a long TDD in the myopic property market.

Fifth, a non-vital neighborhood (*deltract*) lengthens a tax delinquency spell. An ICP in a neighborhood with tax delinquent ICPs highly concentrated is likely to be in tax arrears for a long time. The estimation results suggest that if delinquent taxes of a neighborhood doubles from the population average, $ 8.1, then an ICP in the neighborhood is likely to experience about an 18 days longer tax delinquency spell on average and a tax delinquent ICP a 13 days longer spell. The interpretation of these results is that there is a neighborhood effect from economic non-vitality, though the magnitude of the effect is not large.

Sixth, the location of an ICP influences its TDD. While some of the variables here have a theoretical foundation, linked to accessibility attributes relative to highways or CBD, others are unique to the Cleveland geography and perhaps relevant only to the time period from which the data are drawn and hence, have no generalizable meaning. Two variables are counted in the model, distance to an Interstate Highway (*dis_ihw, east_disihw, hwsq*) and distance to the CBD (*dis_cbd, east_discbd, cbdsq, ecbdsq*). The two variables enter the model in quadratic forms and thus the marginal effects systematically vary with the values of the variables. Hence it is more interesting to see these systematic changes of marginal effects than to see the average effects, as it sheds light on the highly concentrated location of ICPs with the longest TDDs. Another thing to note is that the two variables have different effects in the west and east of the Cuyahoga River.

Consider first distance to an Interstate Highway, which represents the accessibility of an ICP. The estimation results suggest that TDD increases with distance to an Interstate Highway in the beginning and later on decreases with it. Everything else being equal, TDD will be the longest at the turning point. The turning point is about 1.2 miles in the west of the Cuyahoga River, while it is 1.7 miles in the east. Considering that the average distance is 0.89 miles, the marginal effect is overall positive. These results make sense because good accessibility is likely to raise the demand for a property and thus shortens tax delinquency spells.

Consider next distance to the CBD. The estimation results suggest that TDD increases first and then decreases with distance to the CBD in the east, while the opposite is true in the west. The turning points are about 2.3 miles in the east and about 14.2 miles in the west. The turning point in the east is smaller than the average distance, 6.48 miles, which means that the two opposite effects of distance to the CBD clearly show up depending on the distance to the CBD. In the east, the duration increases up to 2.3 miles from the CBD and then decreases. In the west, however, the turning point is much larger than the average distance to the CBD, 7.31 miles, which means that the marginal effect is overall negative in the west. Therefore TDD overall decreases with distance to the CBD in the west.

Seventh, the other variables turn out to have reasonable effects. First, TDD of an ICP follows the time trend (*trend*) of the whole ICPs in the region. The estimation results show that 1 percentage point increase in the fraction of tax delinquent ICPs leads to about a 50 day increase in TDD for all ICPs, and about a 37 day increase for tax delinquent ICPs. Given the trend represents a business cycle, the results make perfect sense because a firm should be influenced by that cycle. Second, stability of a firm (*indust*) reduces TDD. The industrial land use represents stability of a firm once controlling for industrial growth rates, as entry and exit of manufacturing firms tend to be more difficult than for commercial firms. The estimation results show that everything else being equal, industrial use leads to a 6.7 month decrease in the duration for all ICPs and a 4.8 month decrease for tax delinquent ICPs.

All these results well verify the theoretical predictions in Section 4.3.1. Similar results will be shown for the abandonment probability model in the following section as well.

4.4.2.2 Abandonment probability model

As mentioned in Section 4.2.1, an abandoned ICP is identified with the one experiencing 18 months or longer period of tax delinquency. We construct a special model for the probability of these abandonment events (in short, abandonment probability) using two binary response models, probit and logit. We use only the data of ICPs for which it is known whether an abandonment event has occurred or not. In other words, we exclude the data of ICPs, whose tax delinquency spell is censored before reaching 18 months. We also compare the marginal effects of explanatory variables computed on the basis of the binary models with those based on the Tobit model, as explained in Section 4.3.2.

Dependent Variable: *abnd*								
Independent Variable	Probit				Logit			
	Estimate	Standard Error	t Value	Approx Pr > |t|	Estimate	Standard Error	t Value	Approx Pr > |t|
trend	0.056777	0.003679	15.43	<.0001	0.106711	0.006994	15.26	<.0001
logsfval	-0.119927	0.015126	-7.93	<.0001	-0.234688	0.029636	-7.92	<.0001
bldg	0.608374	0.069245	8.79	<.0001	1.118582	0.123608	9.05	<.0001
bldgcond	-0.120094	0.012770	-9.40	<.0001	-0.221866	0.023487	-9.45	<.0001
zpempgr	-0.134012	0.064278	-2.08	0.0371	-0.227257	0.116957	-1.94	0.0520
empgrw	-0.101383	0.037886	-2.68	0.0075	-0.197513	0.073870	-2.67	0.0075
deltract	0.004899	0.000474	10.33	<.0001	0.008204	0.000897	9.14	<.0001
convrt	0.249275	0.032530	7.66	<.0001	0.437422	0.058069	7.53	<.0001
dis_cbd	-0.046432	0.013527	-3.43	0.0006	-0.068148	0.027706	-2.46	0.0139
east_discbd	0.123254	0.013728	8.98	<.0001	0.244415	0.028193	8.67	<.0001
cbdsq	0.001050	0.000883	1.19	0.2343	0.000569	0.001850	0.31	0.7583
ecbdsq	-0.010054	0.001113	-9.03	<.0001	-0.020252	0.002339	-8.66	<.0001
dis_ihw	0.253738	0.049794	5.10	<.0001	0.433022	0.100010	4.33	<.0001
east_disihw	0.041593	0.041076	1.01	0.3113	0.080586	0.087851	0.92	0.3590
hwsq	-0.095578	0.015091	-6.33	<.0001	-0.173818	0.028712	-6.05	<.0001
indust	-0.320564	0.029481	-10.87	<.0001	-0.601957	0.056501	-10.65	<.0001
txrate	0.005610	0.001176	4.77	<.0001	0.012020	0.002244	5.36	<.0001
sale	0.407157	0.050035	8.14	<.0001	0.722180	0.090024	8.02	<.0001
acre	0.002255	0.001390	1.62	0.1048	0.003410	0.002679	1.27	0.2031
intercept	-2.088719	0.118804	-17.58	<.0001	-3.862247	0.226479	-17.05	<.0001
Number of observations		27,068				27,068		
Percent correctly predicted		85.08				85.14		
abnd = 1		31.30				31.54		
abnd = 0		92.53				92.56		
Log-likelihood value		-8,751				-8,744		
Pseudo *R*-squared		.1267				.1274		

Table 4.3: Full Regression Results for Abandonment Probability

The full results of MLE are reported in Table 4.3. The table shows the coefficient estimates for explanatory variables with inference statistics. Marginal effects on abandonment probability of explanatory variables are shown in Table 4.4 separately. Three estimates from the three models are shown side by side. They are all evaluated at the mean values as with the Tobit model.

The performance of the model is overall good. Most of the *t*-values and *p*-values are very good for the explanatory variables except for *cbdsq*, *east_disihw*, and *acre*. Even if they are not significant in explaining the dependent variable, we include them to make it easy to compare the results of the binary response models with those of the Tobit model. The measures of goodness-of-fit of the model also suggest that the model's explanatory power is good. The percent correctly predicted is calculated as follows: Define a binary predictor $\widetilde{abnd}_i$ of *abnd* to be one if the predicted probability is a threshold value τ and zero otherwise, where the threshold value[31] is picked such that $\sum_{i=1}^{n} \widetilde{abnd}_i = \sum_{i=1}^{n} abnd_i$. Given this set of $\widetilde{abnd}_i$, compute the percentage of times that the predicted values are equal to the actual values. The percentage is relatively low for the outcome of abandonment, as expected, but overall it is not bad. The reported pseudo R-squared is calculated following McFadden (1974) as usual with binary response models. The values are also not bad, in view of the facts that the pseudo R-squared is usually much less than the OLS type of R-squared and that a relatively small number of explanatory variables are being used. Moreover, all the signs of the coefficients are consistent with the theory and the Tobit model.

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[31] The thresholds are .24252 for the probit and .24270 for the logit model. Traditionally, .5 has traditionally been used as a threshold value, but this rule is not good for a case where one of the outcomes is unlikely as with the case in this study. In order to overcome this shortcoming, we adopt a new threshold value smaller than .5 following as Wooldridge (2006) suggests.

Let’s look at the marginal effect on abandonment probability of each variable as shown in Table 4.4. The table shows the estimates of the three models and their average. The first two are computed using (4.18) and (4.19) from the binary response models where the dependent variable is a binary response of whether or not an abandonment event occurs. The third is derived using (4.15) and (4.16) from the Tobit model where the dependent variable is TDD as explained in Section 4.3.2.2. As shown in the table, the estimates are parallel to each other. This suggests that the estimates of the models are overall stable and reliable.

Dependent Variable: *abnd*				
Independent Variable	Probit	Logit	Tobit	Average
trend	0.01811	0.02115	0.03293	0.02406
logsfval	-0.03826	-0.04652	-0.02783	-0.03754
bldg	0.15107	0.10778	0.16330	0.14072
bldgcond	-0.03831	-0.04398	-0.03290	-0.03840
zpempgr	-0.04275	-0.04505	-0.05925	-0.04902
empgrw	-0.03234	-0.03915	-0.06529	-0.04559
deltract	0.00156	0.00163	0.00142	0.00154
convrt	0.07253	0.06586	0.06865	0.06901
dis_cbd	-0.01481	-0.01351	-0.02340	-0.01724
east_discbd	0.03932	0.04845	0.03092	0.03956
cbdsq	0.00033	0.00011	0.00083	0.00042
ecbdsq	-0.00321	-0.00401	-0.00242	-0.00321
dis_ihw	0.08095	0.08584	0.08349	0.08343
east_disihw	0.01327	0.01598	0.03801	0.02242
hwsq	-0.03049	-0.03446	-0.03527	-0.03341
indust	-0.11203	-0.16225	-0.12379	-0.13269
txrate	0.00179	0.00238	0.00082	0.00166
sale	0.11086	0.09007	0.09331	0.09808
acre	0.00072	0.00068	0.00101	0.00080

Table 4.4: Marginal Effects on Abandonment Probability

Since the interpretation is similar to that with the Tobit model, we do not need to repeat it here. The only difference is that the marginal effect of an explanatory variable is on the probability of an abandonment event taking place. For instance, see the effect of regional growth (*zpempgr*). The marginal effect estimates are between -0.043 (probit) and -0.059 (Tobit), and the average is about -0.049, which means that a 10 percentage point increase in the regional growth rate lowers the probability of abandonment by about 0.49 percentage point.

In order to see the spatial distribution of abandoned ICPs, see the effects of the location variables in more detail. The patterns of the effects are parallel to those with the duration model. First, the probability of abandonment increases with distance to an Interstate Highway in the beginning and later on decreases with it. As mentioned earlier, the Tobit model implies that the turning points are 1.7 miles in the east and 1.2 miles in the west. The two binary models imply that they are 1.5 miles (probit and logit) in the east and 1.2 miles (logit) or 1.3 miles (probit) in the west. Recall that distance to an Interstate Highway in the east (east_disihw) is not significant. Thus we can conclude that the turning point is about between 1.2 and 1.3 miles in all the regions.

Next, the probability of abandonment increases first and then decreases with distance to the CBD in the east, while it decreases monotonically in the west because of insignificance of the second degree term (*cbdsq*). The Tobit model implies that the turning point in the east is 2.3 miles, while the binary models suggest that its 4.3 miles (probit) or 4.5 miles (logit). The turning point estimates in the east are smaller than the average distance, 6.48 miles, which means that the two opposite effects of distance to the CBD clearly show up depending on the distance to the CBD. In the east, the probability of abandonment increases up to 2.3 miles or 4.5 miles from the CBD and then decreases. These results imply that a belt of abandoned ICPs is formed in the east. The map in Figure 4.1: Spatial Distribution of Tax Delinquent ICPs confirms this interpretation. The ICPs with 18 months or longer period of tax delinquency, represented by red dots, are indeed concentrated in the belt of 2 – 5miles from the CBD in the east of Cuyahoga River.

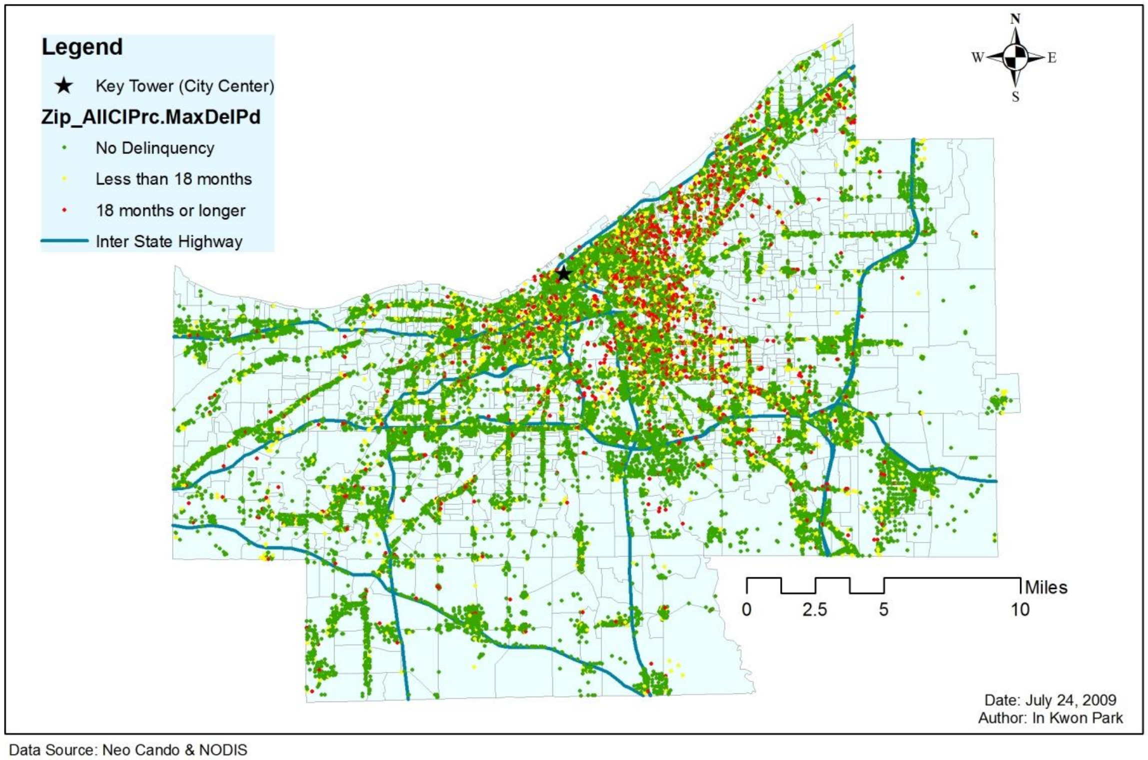

Figure 4.1: Spatial Distribution of Tax Delinquent ICPs

The results of the model suggest that abandoned ICPs are likely to be spatially concentrated in specific zones. The zones are located in a 2 – 5 mile belt from the CBD in the east of the Cuyahoga River, and in economically non-vital neighborhoods with high tax delinquency rates. The reason for this spatial concentration is related to the history of the Cleveland region. An industry cluster consisting of similar sub-industries was formed to exploit localization economies in the east of Cuyahoga River in the Cleveland region. While in its early history the cluster gained a lot of positive externalities from the agglomeration, it has been suffering from decline since the

1960s due to the deindustrialization and industrial restructuring in the era of the new economy. The decline of the industrial cluster may lead to a cluster of abandoned ICPs.

Another reason is related to the negative spillovers of abandoned properties, as explained in Section 4.2.1. Even after controlling for economic growth variables, the neighborhood variables such as distance to the CBD and neighborhood vitality are significant in the models. This implies that there is a neighborhood effect impacting TDD and abandonment potential. Particularly industries such as retails sensitive to neighborhood amenities will be influenced by these spillovers, as a retailer is likely to lose its customers as its neighborhood declines.

4.5 Conclusion

This paper looks at vulnerable industrial and commercial properties (ICPs) of an old industrial region in the era of the new economy. Specifically, it explains which ICPs are abandoned, and what factors determine their vulnerability to economic challenges. We use property tax delinquency as an indicator of vulnerability of ICPs to economic challenges and as an early indicator of property abandonment. Using the data of the Cleveland region, we find that economic growth/decline and conversion costs impact the TDD and thus abandonment probability of ICPs as well, along with other variables of individual property and neighborhood characteristics, and policy instruments.

We theoretically predict and empirically verify that an ICP of a fast declining industry and region is more likely to be tax delinquent for a long time and is also more likely to be abandoned than an ICP of a growing or at least slowly declining industry and region. Faced with the decline of an industry and region, an ICP should be converted from one use to another, incurring conversion costs. We also find that an ICP that requires more conversion and higher conversion costs is more likely to experience a longer tax delinquency duration and thus is more likely to be abandoned than others. Another interesting finding is that abandoned ICPs are spatially concentrated in specific zones, possibly due to the history of industrial clustering and negative spillovers of abandonment.

These findings allow local authorities to predict the vulnerability of ICPs and to deal with the problem through appropriate policy instruments such as property tax mitigation and rezoning. Negative externalities of abandoned properties justify government intervention. To reduce abandonment, the local government can introduce the following instruments: First, property tax mitigation can be used to reduce the abandonment probability of vulnerable ICPs. Recall that a property tax is a type of maintenance cost and thus lowering it delays the starting point of tax delinquency. Second, rezoning is also a good policy tool to facilitate conversion of ICPs. An ICP of a declining industry has to be converted to another use eventually, and it may require rezoning. The local government's rezoning in time will facilitate the process of conversion. Third, spatially selective policies will be efficient in dealing with the abandonment problem. Abandoned ICPs tend to be concentrated in specific zones. It may be a good idea to approach the concentrated zones from the outside incrementally as usual with many other revitalization efforts.

This paper has some limits. The models have limited prediction power for the outcome of abandonment, because a small number of explanatory variables are being used relative to the number of observations. Decision of tax delinquency and abandonment of an ICP should depend heavily on the financial situation of the firm on a parcel. Thus one may need the financial data such as stock prices and balance sheets in order to predict the abandonment of an individual property more accurately. Incorporating those variables into the models will raise its predictive power, but the historical data are not readily available for those data. Thus the extension is reserved for future research. Some technical problems such as the endogeneity problem of some explanatory variables and the non-normality problem of the duration data will also be dealt with later on.

Chapter 5: Negative Externalities of Abandonment and Pigouvian Subsidy

5.1 Introduction

Chapter 3 discussed abandoned properties and mentioned the possibility that they generate negative spillovers. It suggested that negative externalities may extend the abandonment period and result in a cycle of decay. However, it did not model this. The current chapter seeks to alleviate this problem.

The model considered here is a simplified version of the model considered in Chapter 3, but it models explicitly real and pecuniary externalities. It is simplified in the sense that it deals only with the reuse of property that has already been abandoned. It is further simplified in that abandoned property does not incur property taxes that might have to be paid off during the reuse. However, the property imposes negative real spillovers. If the property is fragmented, then these spillovers are on the fragmented parts of the property, in addition to spillovers beyond. In the real world, one may consider a small Ohio town with a small commercial center surrounding the Central Square, say with a total 100 commercial properties. Each property has an impact on other properties in the Center, and the Center as a whole has real spillovers to the area outside. Further, Center properties are a significant part of the commercial properties in the town, and hence there are pecuniary spillovers from its reuse on property values within the town, both commercial and residential. The model considers remodeling of the abandoned Center, once by a single owner and once by fragmented individual property owners. The single owner will internalize both the real externalities (inside the Center) and the pecuniary externalities (inside the Center), while the fragmented owners are assumed to regard as external both types of externalities. The Municipal Government in pursuing a social optimum will consider all types of externalities, both inside and outside the Center and both real and pecuniary.

A similar story can be told at the much larger metropolitan scale, where either single national developers are responsible for new edge cities, or where such cities develop spontaneously through incremental decision making. Hence, this chapter also contributes to the literature on alternative source of polycentric and edge city development. While in this case, initially there are no negative externalities from abandonment, positive externalities are created from development, and mathematically, the two situations are analogous. Also, both real and pecuniary externalities play an important role in edge city development, and in the controversy typically surrounding the creation of such cities. A commercial edge city may have large pecuniary impacts on commercial property throughout a metropolitan area, leading to asymmetric benefits between the home county of the edge city and the remaining counties in a metropolitan region.

Abandoned properties generate negative spillovers, both on production and consumption. Abandoned properties result in disamenities for residents in surrounding neighborhoods and a decline in productivity to remaining firms. The model in Chapter 3 (denoted below by 'the previous model') showed that negative externalities may extend the abandonment period and result in a cycle of decay.

Private agents do not take into account abandonment externalities when making decisions about the reuse or potential abandonment of legacy property and hence, unfettered markets lead to too much abandonment, longer periods of abandonment, and too little conversion than socially optimal. Correction of this market failure requires government intervention to facilitate the timely conversion of properties to new uses.

The size of externality impacts depends on the level and spatial concentration of abandonment. The more pervasive abandonment the greater is the loss of productivity for each of the remaining firms. However, the total impact on a city or neighborhood eventually declines, as the number of firms remaining in operation falls with rising abandonment. In a city in which all property has been abandoned, the externality impact on operating firms declines to zero. The impact also depends on the ownership fragmentation of abandoned properties. When a large abandoned property is converted by a single owner, she is more likely to account for the productivity gain of the conversion and its impact on the output market. When ownership is fragmented and many small properties are converted by their many owners, each likely will not account for the effects of conversion on others.

This chapter models the externalities involved in the abandonment and conversion of abandoned properties, and suggests a Pigouvian subsidy for the conversion cost in order to restore the social optimum. It identifies the optimal level of subsidy to maximize social surplus as a function of the ratio of abandoned to used properties, and compares the conversion of abandoned property for fragmented vs. single ownership.

5.2 Settings

Suppose that a large property is released and abandoned by the manufacturing sector in a city at time t_f. It occupies a share θ of total developable non-residential properties in the city. The rest $1-\theta$ is being used by the commercial sector whose good is place-specific and differentiated from other cities' commercial good. Let L, L_A and L_E denote the sizes of the total properties, the abandoned properties and the properties employed by the commercial sector, respectively, and L_{iE} denote the size of the property employed by a commercial firm i. Then

$$\frac{L_A}{L_E} = \frac{\theta}{1-\theta}, \text{with } L_E = \sum_i L_{iE} \tag{5.1}$$

For simplicity, assume that land available for commercial use is limited only to the current employed property and the newly released property. This can be interpreted as follows: The commercial sector requires a unique location, say close to the CBD, and the transportation and infrastructure costs are so high that an alternative suburban location is not feasible. The relaxation of this restriction will lead to an upper limit to the price of the released property, imposed by the floor price, transportation costs, and new development costs. If the upper limit is smaller than zero, then the property must be abandoned permanently and its price must be zero, which is not an interesting case for us. If the upper limit is greater than zero but very low, then the price must be the same as the limit and the property must be abandoned only until the offer price of the new sector becomes equal to the limit. For now assume that the upper limit is large enough not to influence the price.

The commercial sector is assumed to be in the same situation as in the previous model. The sector is originally in a stationary state until it starts to grow at time 0. The demand schedule for the commercial good is iso-elastic and is expected to grow at a constant rate μ_y from time 0 as in the previous model:

$$Q_t^D = Y_t P_t^{-\sigma}, \sigma > 1 \; with \; Y_t = Y_0 e^{\mu_y t} \text{ for } t \geq 0, 0 \leq \mu_y < \mu_x \tag{5.2}$$

where σ is the price elasticity of demand, Q_t^D is the total quantity at market, and P_t is the output price and Y_t is the coefficient of the demand function that is impacted by the total income of consumers and the prices of substitutes for the good. The commercial sector is composed of many small firms that employ the same constant return technology, though their size may vary. The production in the commercial sector can be modeled based on a firm representative of this technology, though its size may differ from that of other firms. The firm produces output at time *t* using capital, labor, and real property. The production function is

$$q_t = A_t K_t^{\alpha} N_t^{\beta} L_t^{\nu}, \qquad 0 < \alpha, \beta, \nu < 1 \; and \; \alpha + \beta + \nu = 1$$

where A_t is total factor productivity (TFP), q_t is output, K_t is capital, N_t is labor, and L_t is realty. The wage rate of labor, the price of capital, and the price of realty are exogenously given at w, p_K, and $\bar{p}_L$, respectively. Faced with rising industry demand, the representative commercial firm increases investment in the existing property and wants to expand the business on the property newly released by the manufacturer.[32] However, the conversion from manufacturing to commercial use incurs conversion costs in addition to the price of the property. So the conversion does not occur until the firm's operating profit becomes large enough to cover this cost.

The manufacturer is willing to hold its property in expectation of a rise in the property price. She behaves as an asset manager, and sells its property to a commercial firm at an appropriate price to maximize the proceeds. Further, similar to the previous model, assume that holding a property incurs no financial costs. If instead, there was a financial cost, for example in the form of a property tax during abandonment, then the manufacturer would sell-off the property earlier and the commercial firm would delay its entry. The two effects offset each other. Since otherwise there is little change, we assume no financial cost.

[32] Since the product is differentiated by city as assumed earlier and the entry is limited by the availability of land, the existing firms expand to satisfy the rising demand.

5.3 Externalities of Conversion of Legacy Property

The conversion of an abandoned property brings about two types of externalities: real (or technical) externality and pecuniary externality. Real externality refers to gains both on consumption and production due to the removal of negative real spillovers from crime, vandalism, physical disorder, and decline in attractiveness. Pecuniary externality refers to impacts from change in prices as the conversion raises the level of production and lowers the output price of the commercial sector. If the abandoned property is small, then the pecuniary externality may be negligible. However, if the property is large and the price change is significant, the externality cannot be ignored.

5.3.1 Real Externality

The productivity of commercial firms declines as the share of abandoned properties rises. As abandoned properties are converted to commercial use, the share of abandoned properties declines and the productivity rises again.

Without loss of generality, label abandoned properties from 1 to N in the order of the time of conversion, and define the set of the legacy properties as $I = \{1,2,\cdots\cdots,N\}$. Let θ_j denote the share of the j^{th} legacy property. Then,

$$\sum_{j=1}^{N} \theta_j = \theta$$

Let L_{jA} denote the property size of the j^{th} legacy property. Then, obviously the following must hold:

$$L_{jA} = \frac{\theta_j}{\theta} L_A = \frac{\theta_j}{1-\theta} L_E \tag{5.3}$$

$$\sum_{j=1}^{N} L_{jA} = L_A$$

If the j[th] legacy property is converted, then the share of abandonment at that time, θ_{j+} becomes

$$\theta_{j+} = \sum_{k=1}^{N-j} \theta_{j+k} \tag{5.4}$$

Since productivity is a function of the share of abandonment, one may let $A(\theta_{j+})$ be the productivity during the time period when the abandonment share is θ_{j+}. That is,

$$A_t = A(\theta_{j+}) \text{ for } t_j \leq t \leq t_{j+1} \tag{5.5}$$

where t_j and t_{j+1} are the conversion times for abandoned properties *j* and (*j*+1). Since this function is decreasing in the abandonment share θ_{j+} and the share θ_{j+} is obviously decreasing in *j*, the productivity A_t is increasing in *j*. Formally,

$$A(\theta_{m+}) \geq A(\theta_{n+}), \qquad \text{for all } m \geq n \text{ and } m, n \in I$$

5.3.2 Pecuniary Externality

Commercial firms are assumed to be price takers. This includes new firms on abandoned property. Once they have entered business, they do not anticipate price changes resulting from their own action.[33] They also are assumed to be myopic in the sense that they cannot precisely foretell the future share of abandoned properties. Rather, they assume the current abandonment share to continue into the future. Recall that the production by the firms on the originally employed property is given by

[33] But the firm must take into account the price change when it decides the entry time to get a zero profit from operating the firm.

$$q_{it} = \left[A_t \left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{\beta} P_t^{\alpha+\beta}\right]^{\frac{1}{\nu}} L_{iE}$$

The production by the firm that converts the *j*th legacy property is given in the same way, that is,

$$\tilde{q}_{jt} = \left[A_t \left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{\beta} P_t^{\alpha+\beta}\right]^{\frac{1}{\nu}} L_{jA}$$

Hence the total market supply Q_{jt}^{SS} of the commercial good at time t by when legacy properties from 1 to j have been converted is given by

$$Q_{jt}^{SS} = \sum_{i} q_{it} + \sum_{k=1}^{j} \tilde{q}_{kt} = \left[A_t \left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{\beta} P_t^{\alpha+\beta}\right]^{\frac{1}{\nu}} \left(\sum_{k=1}^{j} L_{kA} + L_E\right)$$

Using (5.3), (5.4), and (5.5) yields

$$Q_{jt}^{SS} = \frac{1-\theta_{j+}}{1-\theta}\left[A(\theta_{j+}) \left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{\beta} P_t^{\alpha+\beta}\right]^{\frac{1}{\nu}} L_E = \left(\frac{1-\theta_{j+}}{1-\theta}\right)\left[\frac{A(\theta_{j+})}{A(\theta)}\right]^{\frac{1}{\nu}} Q_t^S \qquad (5.6)$$

where $Q_t^S = \left[A(\theta) \left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{\beta} P_t^{\alpha+\beta}\right]^{\frac{1}{\nu}} L_E$ is the market supply at time *t* without the entry of the new firm. Recall from the previous paper that is given by

$$Q_t^S = \frac{Q_0}{A_0} A(\theta)^{\frac{1}{\nu}} \left[\left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{\beta} \left(\frac{\nu}{l}\right)^{\nu} P_t\right]^{\frac{\alpha+\beta}{\nu}} \qquad (5.7)$$

where Q_0 and $A_0 = A(0)$ are the market supply and the productivity in stationary equilibrium prior to time 0, respectively. In other words, for a given output price, the market supply increases in proportion to the increase in realty input.

However, an increase in market supply leads to a fall in output price. The new equilibrium price P_{jt}^{EE} is derived by equating the market supply and demand. The result is

$$P_{jt}^{EE} = \left(\frac{1-\theta}{1-\theta_{j+}}\right)^{\eta\nu} \left[\frac{A_0}{A(\theta_{j+})}\right]^{\eta} P_0 e^{\mu\nu t} \tag{5.8}$$

where $\eta = 1/(\alpha + \beta + \sigma\nu)$ and $P_0 = (1/A_0)(c/\alpha)^{\alpha}(w/\beta)^{\beta}(l/\nu)^{\nu}$ is the output price in stationary equilibrium prior to time 0 without abandonment. Recall from the previous paper that the equilibrium output price P_t^E at time *t* without the new firm's production is written as

$$P_t^E = \left[\frac{A_0}{A(\theta)}\right]^{\eta} P_0 e^{\mu\nu t} \tag{5.9}$$

Hence P_{jt}^{EE} is rewritten as

$$P_{jt}^{EE} = \left(\frac{1-\theta}{1-\theta_{j+}}\right)^{\eta\nu} \left[\frac{A(\theta)}{A(\theta_{j+})}\right]^{\eta} P_t^E \tag{5.10}$$

In other words, the new equilibrium price slightly changes by the factor $\left[(1-\theta)/(1-\theta_{j+})\right]^{\eta\nu}\left[A(\theta)/A(\theta_{j+})\right]^{\eta}$ from the original output price that would be formed without any impact of abandonment or conversion. The first factor is related to the pecuniary externality of the conversion of the properties from 1 to j, while the second factor is related to the real externality of the abandoned properties from *j*+1 to N. As the conversion goes on, the first becomes smaller and the second larger. Hence the net effect of conversion on the price is not predetermined but determined by the productivity function and parameter values.

5.4 Fragmented vs. One-shot Conversion.

The conversion of legacy property can be done in two ways: fragmented conversion and one-shot conversion. In the first case, the conversion is attained by many small firms. Each of them buy a small piece of legacy property and convert it separately. This can be interpreted as the case where the ownership of legacy capital is fragmented. In the second case, the conversion is attained by only one large commercial firm. The firm buys the whole property and converts it to commercial use at once. This can also be interpreted as the case where small firms cooperate in the conversion of legacy properties or where the Government uses eminent domain or other means to enforce a simultaneous conversion – the standard approach of urban renewal in decades past.

5.4.1 Fragmented Conversion

In the fragmented conversion case, legacy property is composed of N small properties under separate ownership. A commercial firm buys a small property and converts it to commercial use. Each commercial firm can observe only the current share of abandoned property, but does not know how the share changes in the future. More precisely, each firm expects that its entry is the last change in the composition of abandoned properties and employed properties.

Based on this myopic expectation, the new commercial firm expects that its current productivity will continue in the future. The j^{th} firm converting legacy property expects its productivity to be

$$A_t = A(\theta_{j+}) \text{ for } t \geq t_e$$

This expectation may not be validated because more legacy property may be converted later and thus productivity goes up accordingly. However, as the firm does not know the course of future events, it holds to its myopic expectation.

As a price taker, the j^{th} firm's investment plan for the property is given in the same way as in the previous model as follows:

$$\widetilde{K}_{jt} = \left[A(\theta_{j+})\left(\frac{\alpha}{c}\right)^{1-\beta}\left(\frac{\beta}{w}\right)^{\beta} P_t\right]^{\frac{1}{\nu}} L_{jA}$$

$$\widetilde{N}_{jt} = \left[A(\theta_{j+})\left(\frac{\alpha}{c}\right)^{\alpha}\left(\frac{\beta}{w}\right)^{1-\alpha} P_t\right]^{\frac{1}{\nu}} L_{jA}$$

$$\tilde{\pi}(\widetilde{K}_{jt}, \widehat{P}_t; L_{jA}) = (1-\beta)\left[A(\theta_{j+})\left(\frac{\alpha}{c}\right)^{\alpha}\left(\frac{\beta}{w}\right)^{\beta} P_t\right]^{\frac{1}{\nu}} L_{jA}$$

$$\tilde{I}_{jt}^{*} = \begin{cases} \widetilde{K}_{jt_e} & \text{for } t = t_e \\ (\mu+\rho)\widetilde{K}_{jt_e} & \text{for } t_e < t < T \\ -\widetilde{K}_{jT} & \text{for } t = T \end{cases}$$

where the output price P_t is expected to be determined by (5.8). Hence its optimal inputs, the operating profit, and the optimal investment in capital over time are given

$$\widetilde{K}_{jt} = \left(\frac{1-\theta}{1-\theta_{j+}}\right)^{\eta}\left[\frac{A(\theta_{j+})}{A_0}\right]^{\epsilon}\frac{\alpha l}{c\nu} L_{jA} e^{\mu t}$$

$$\widetilde{N}_{jt} = \left(\frac{1-\theta}{1-\theta_{j+}}\right)^{\eta}\left[\frac{A(\theta_{j+})}{A_0}\right]^{\epsilon}\frac{\beta l}{w\nu} L_{jA} e^{\mu t}$$

$$\tilde{\pi}(t; L_{jA}) = \left(\frac{1-\theta}{1-\theta_{j+}}\right)^{\eta}\left[\frac{A(\theta_{j+})}{A_0}\right]^{\epsilon}\frac{(1-\beta)l}{\nu} L_{jA} e^{\mu t}$$

$$\tilde{I}_{jt}^{*} = \begin{cases} \widetilde{K}_{t_e} = \left(\frac{1-\theta}{1-\theta_{j+}}\right)^{\eta}\left[\frac{A(\theta_{j+})}{A_0}\right]^{\epsilon}\frac{\alpha l}{c\nu} L_{jA} e^{\mu t_e} & \text{for } t = t_e \\ (\mu+\rho)\widetilde{K}_{t_e} = \left(\frac{1-\theta}{1-\theta_{j+}}\right)^{\eta}\left[\frac{A(\theta_{j+})}{A_0}\right]^{\epsilon}\frac{\alpha l(\mu+\rho)}{c\nu} L_{jA} e^{\mu t_e} & \text{for } t_e < t < T \\ -\widetilde{K}_T = -\left(\frac{1-\theta}{1-\theta_{j+}}\right)^{\eta}\left[\frac{A(\theta_{j+})}{A_0}\right]^{\epsilon}\frac{\alpha l}{c\nu} L_{jA} e^{\mu T} & \text{for } t = T \end{cases}$$

where $\epsilon = \eta(\sigma-1) > 0$. This expectation may not be validated again because more legacy property may be converted in the future and thus productivity goes up accordingly.

In an infinite time horizon, the value at the entry time of operating the firm that enters the business on legacy property *j* at time t_e is given by

$$V_{jt_e}(\tilde{p}_L) = \left(\frac{1-\theta}{1-\theta_{j+}}\right)^{\eta} \left[\frac{A(\theta_{j+})}{A_0}\right]^{\epsilon} \frac{r\bar{p}_L L_{jA}}{r-\mu} e^{\mu t_e} - [\tilde{p}_L L_{jA} + S_j]$$

where S_j is the conversion cost for a abandoned property j. The competitive property market condition requires that the equilibrium price of the legacy property at time t should be

$$\tilde{p}^*_{jL}(t_e) = \left(\frac{1-\theta}{1-\theta_{j+}}\right)^{\eta} \left[\frac{A(\theta_{j+})}{A_0}\right]^{\epsilon} \frac{r}{r-\mu}\bar{p}_L e^{\mu t_e} - \frac{S_j}{L_{jA}}$$

Equivalently, the commercial firm's entry time for a given price of the property is given by

$$t^*_{je}(\tilde{p}_L) = \frac{1}{\mu}\log\frac{\tilde{p}_L L_{jA} + S_j}{\bar{p}_L L_{jA}} - \frac{1}{\mu}\log\frac{r}{r-\mu}\left(\frac{1-\theta}{1-\theta_{j+}}\right)^{\eta} \left[\frac{A(\theta_{j+})}{A_0}\right]^{\epsilon} \quad (5.11)$$

The manufacturer as an asset manager tries to maximize the present value of the proceeds from selling its property. Hence its problem is the same as that of the local government in the previous model. So its asking price is given by

$$\tilde{p}^*_L = \frac{1}{r}\left(\frac{\partial t^*_e}{\partial \tilde{p}_L}\right)^{-1} \quad (5.12)$$

The Nash Equilibrium is obtained by solving (5.11) and (5.12) simultaneously. The result is that

$$t^*_{je} = \frac{1}{\mu}\log\frac{S_j}{\bar{p}_L L_{jA}} + \frac{\eta}{\mu}\log\frac{1-\theta_{j+}}{1-\theta} + \frac{\epsilon}{\mu}\log\frac{A_0}{A(\theta_{j+})} \quad (5.13)$$

$$\tilde{p}^*_{jL} = \frac{\mu S_j}{(r-\mu)L_{jA}} \quad (5.14)$$

The intuition behind this is that the abandonment period $t^*_{je} - t_f$ becomes longer, the higher the conversion cost per unit property size ant the initial share θ of abandonment. It also extends more, the lower the growth rate of the commercial sector. Note that the abandonment condition that the property must be abandoned for some time requires $t^*_{je} > t_f$ for all the abandoned properties. Formally,

$$\frac{S_j}{\bar{p}_L L_{jA}} > \left(\frac{1-\theta}{1-\theta_{j+}}\right)^{\eta} \left[\frac{A(\theta_{j+})}{A_0}\right]^{\epsilon} e^{\mu t_f} \text{ for all } j \in I$$

The last two terms of (5.13) are associated with the two types of externalities. The second term represents a delay due to the pecuniary externality of conversion. The third term represents a delay due to the real externality of abandonment. As the conversion of abandoned properties goes on, the pecuniary externality gets larger while the real externality gets smaller. As a result, the net effect is ambiguous. As each converted property is very small, one additional conversion does not make much difference in these externalities. That is,

$$\frac{\eta}{\mu}\log\frac{1-\theta_{j+}}{1-\theta} + \frac{\epsilon}{\mu}\log\frac{A_0}{A(\theta_{j+})} \approx \frac{\eta}{\mu}\log\frac{1-\theta_{k+}}{1-\theta} + \frac{\epsilon}{\mu}\log\frac{A_0}{A(\theta_{k+})}$$

for any $j \in I$ and $k = j + 1$

So in this model, differences in conversion time across abandoned properties come from differences in conversion cost per unit property size, S_j/L_{jA}.

Consider the case where different properties have different conversion costs. In this case, the later a conversion occurs, the higher its cost as properties with a low cost will be converted first. That is,

$$\frac{S_k}{L_{kA}} > \frac{S_j}{L_{jA}} \text{ for all } k > j$$

If this condition is met, then the abandoned properties will be converted at different times. Further suppose that the conversion cost per unit property size is increasing/decreasing in property size, which is the case if the conversion cost is a convex/concave function of property size. Then the conversion time is later, the larger/smaller the property size.

Consider the case where the conversion cost per unit property size is a constant, which is the case if the conversion cost is a linear function of property size. Then the conversion times are the same across all abandoned properties of different sizes. The conversions must occur at the time when the abandoned property 1 is converted. The common conversion time t_{Fe}^* and the property price $\tilde{p}_{FL}^*$ are

$$t_{je}^* = \frac{1}{\mu}\log\frac{S_1}{\bar{p}_L L_{1A}} + \frac{\eta}{\mu}\log\frac{1-\theta_{1+}}{1-\theta} + \frac{\epsilon}{\mu}\log\frac{A_0}{A(\theta_{1+})}$$

$$\approx \frac{1}{\mu}\log\frac{s_0}{\bar{p}_L} + \frac{\epsilon}{\mu}\log\frac{A_0}{A(\theta)} = t_{Fe}^* \text{ for all } j$$

$$\tilde{p}_{jL}^* = \frac{\mu s_0}{r-\mu} = \tilde{p}_{FL}^* \text{ for all } j$$

where $s_0 = S_j/L_{jA}$, $\forall j \in I$ is the unit conversion cost. The approximation must hold because the share θ_1 of the abandoned property 1 is very small and thus $\theta_{1+} \approx \theta$. In other words, they do not take into account the pecuniary externality at all but only the maximum level of real externality of abandonment. Obviously this expectation turns out not to be validated. If they all convert the abandoned properties at the same time, the real externality of the abandonment should disappear and the pecuniary externality of the conversion should come on the stage.

5.4.2 One-shot Conversion

In the one-shot conversion case, one large commercial firm buys all legacy properties and converts them to commercial use. Since only one agent develops the abandoned property, it can expect not only the productivity gain from the conversion, but also the output price change. The firm justifiably expects that the real externality of abandoned properties will disappear and the output price will go down, if it enters business on the properties.

This one-shot conversion can be regarded as a special case of the above-mentioned fragmented conversion where legacy property is fragmented into one large piece. Then the share of the large piece is the same as the share of the whole abandonment, that is,

$$\theta_1 = \theta \text{ and } \theta_{1+} = 0$$

Plugging this into (5.13) and (5.14) yields the equilibrium conversion time t_{Ne}^* and property price as

$$t_{Ne}^* = \frac{1}{\mu}\log\frac{S}{\bar{p}_L L_A} + \frac{\eta}{\mu}\log\frac{1}{1-\theta} \tag{5.15}$$

$$\tilde{p}_{NL}^* = \frac{\mu S}{(r-\mu)L_A}$$

The intuition behind this is that the abandonment period t_{Ne}^* becomes longer, the higher the conversion cost per unit property size ant the initial share θ of abandonment. It also extends more, the lower the growth rate of the commercial sector. Note that the abandonment condition that the property must be abandoned for some time requires $t_{Ne}^* > 0$ for all the abandoned properties. Formally,

$$\frac{S}{\bar{p}_L L_A} > (1-\theta)^{\eta} e^{\mu t_f}$$

The second term of (5.15) is associated with the pecuniary externality of the conversion. A fall in the output price due to the new firm's entry lowers the firm's profit. Considering this effect, the firm has to delay its entry by $(\eta/\mu)\ \log[1/(1-\theta)]$.

Consider the case where conversion cost is a linear function of property size. Then

$$\frac{S}{L_A} = \frac{S_j}{L_{jA}} = s_0 \text{ for all } j \in I \tag{5.16}$$

Using this, the equilibrium conversion time t_{Ne}^* and the property price are computed as

$$t_{Ne}^* = \frac{1}{\mu}\log\frac{s_0}{\bar{p}_L} + \frac{\eta}{\mu}\log\frac{1}{1-\theta}$$

$$\tilde{p}_{NL}^* = \frac{\mu s_0}{r-\mu}$$

The property price is the same as in the fragmented conversion case, while the conversion time is different in the second term.

5.4.3 Comparison

Now compare the fragmented conversion with the one-shot conversion. First, consider the case where the unit conversion cost is constant as in (5.16). The equilibria for the tow cases are $(t_{Fe}^*, \tilde{p}_{FL}^*)$ and $(t_{Ne}^*, \tilde{p}_{NL}^*)$. Obviously, the unit property price is the same for both cases, though the present values may be different depending on the conversion (selling) time:

$$\tilde{p}_{FL}^* = \tilde{p}_{NL}^*$$

The conversion times in equilibria are, however, different in their second terms. The difference is given by

$$t_{FL}^* - t_{NL}^* = \frac{\eta}{\mu} \log\left\{(1-\theta)\left[\frac{A_0}{A(\theta)}\right]^{\sigma-1}\right\}$$

The sign of this difference is not predetermined but depends on the productivity function $A(\theta)$ and the value of the price elasticity of demand σ. For a given share of abandoned properties, this difference is more likely to be positive, the less the productivity and thus the greater the real externality of the abandonment. Specifically, the one-shot conversion occurs earlier than the fragmented conversion, that is, $t_{FL}^* > t_{NL}^*$, if the following condition is met:

$$A(\theta) < A_0(1-\theta)^{\frac{1}{\sigma-1}}$$

The intuition behind this is as follows: In the case of fragmented conversion, the firm cares only about the given negative spillovers of the abandoned properties when it makes a decision on the investment in legacy property because the effect on the output price of its entry is negligible. So when the spillovers are large, it should delay its entry. In the case of one-shot conversion, on the contrary, the firm can expect the effects of its entry on the output price and the productivity. The productivity loss from the abandonment does not matter any longer, but it cares about a fall in the output price. So when the price fall is large, the firm should delay its entry. Therefore, if the real externality is dominant over the pecuniary externality, the one-shot conversion is achieved earlier than the fragmented conversion. If the real externality is smaller, then fragmented conversion is done earlier.

Note also that for a given θ, the one-shot conversion is more likely to occur earlier σ becomes larger. This is because that as σ becomes larger the output price does not change much when the new firm enters. So the firm involved in the one-shot conversion has less incentive to delay the conversion. This means that the one-shot conversion is more proper to restaurants than to housing. [34]

Second, consider the case where the unit conversion cost is increasing/decreasing in property size. In the fragmented conversion, small firms convert abandoned properties intermittently from the smallest/ largest piece to the largest/smallest piece. Individual conversions follow (5.13) and (5.14). In the one-shot conversion, since the unit conversion cost is very high/low, the conversion occurs later/earlier than the fragmented conversions if the two types of externalities are negligible. If the externalities are taken into account, however, the exact comparison must be done numerically using specific parameter values.

5.5 Social Optimum and Pigouvian Subsidy

As mentioned earlier, a conversion of abandoned properties has externalities on the economy such as a productivity enhancement and an output price fall. Although the externalities

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[34] The price elasticities of demand for restaurants and housing are about 2.3 and 1.1, respectively. (de Leeuw, 1971; Houthakker & Taylor, 1966)

have all positive effects on social welfare, a private firm does not take them into account when they make a decision on the conversion. This is true in both the fragmented conversion and the one-shot conversion. In both cases, the firm takes into account only own private profit, not externalities of its conversion of an abandoned property. In this section, let's define a social optimum for the conversion of abandoned properties, and a policy instrument to achieve it.

5.5.1 Social Surplus

When a large abandoned property is converted to a new use, it leads to an increase in output supply. First, it is a matter of course that the additional input of realty leads to an increase in the supply. Second, the conversion removes the negative spillovers (real externality) on the other firms and thus leads to an increase in the supply. Such increases in output supply raise the social surplus, obviously. In order to precisely define social optimum of the conversion of legacy property, one needs first to define an appropriate social surplus function.

As usual, I define the social surplus function as economic surplus, that is, the sum of consumer's surplus and producer's surplus. The effect on social welfare of a conversion of abandoned property can be measured by the change in the social surplus. In Figure 5.1, Q_t^D represents the market demand, and Q_t^S does the original market supply with no conversion and negative spillovers from abandoned property. $\tilde{Q}_t^S$ represents the suppositional market supply with no spillovers, which should be greater than Q_t^S for any given prices. Q_t^{SS} represents the expected market supply with the conversion, which should be greater than $\tilde{Q}_t^S$ for any given prices because of an production increase on the converted property. Then the effect on social welfare of the conversion is represented by ΔSS_t, the area of polygon OAB. The effect comes from two sources: real externality on the other firms and pecuniary externality of the production increase by the new firm. Geometrically, the first effect is presented by the area of polygon OAC, and the second by polygon OBC.

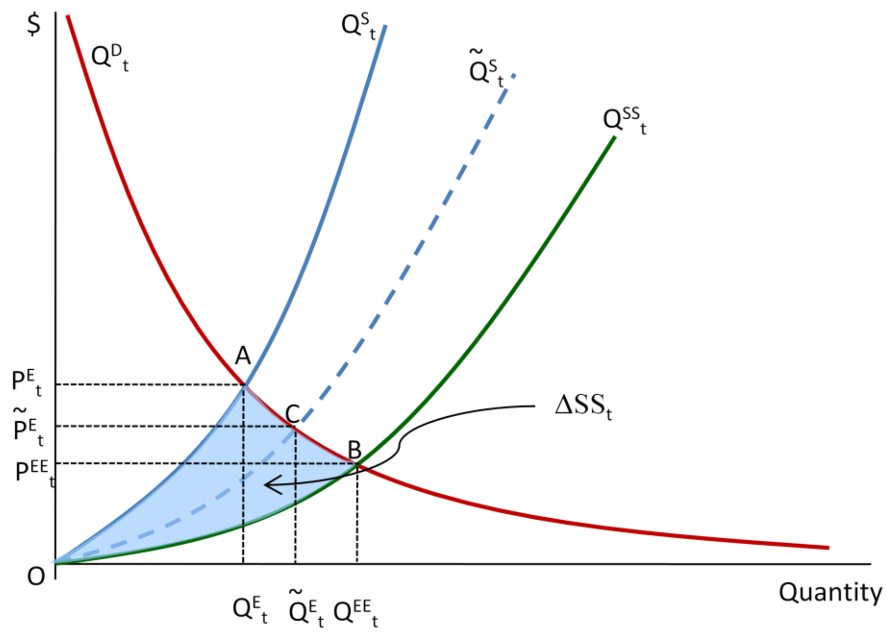

Figure 5.1: Social surplus of conversion of abandoned property

Formally, the social surplus change is given by

$$\Delta \mathrm{SS_t} = \Delta \mathrm{CS_t} + \Delta \mathrm{PS_t}$$

where $\Delta \mathrm{CS_t}$ is the change in consumer's surplus and $\Delta \mathrm{PS_t}$ the change in producer's surplus. The two terms can be computed as

$$\Delta CS_t = \int_{P_t^{EE}}^{P_t^E} Q_t^D \, dP_t \tag{5.17}$$

$$\Delta PS_t = \int_0^{P_t^{EE}} Q_t^{SS} dP_t - \int_0^{P_t^E} Q_t^S dP_t \tag{5.18}$$

where P_t^E is the original market price and P_t^{EE} is the expected market price after the conversion. Obviously the latter is smaller than the first.

For simplicity, suppose that all abandoned properties are converted at once. In the one-shot conversion, the new market supply Q_t^{SS} is obtained by plugging $j = 1$, and $\theta_{1+} = 0$ into (5.6) and (5.7):

$$Q_t^{SS} = \frac{1}{1-\theta} \frac{Q_0}{A_0} A_0^{\frac{1}{\nu}} \left[\left(\frac{\alpha}{c}\right)^{\alpha} \left(\frac{\beta}{w}\right)^{\beta} \left(\frac{\nu}{l}\right)^{\nu} P_t \right]^{\frac{\alpha+\beta}{\nu}} = \frac{1}{1-\theta} \left[\frac{A_0}{A(\theta)}\right]^{\frac{1}{\nu}} Q_t^S \tag{5.19}$$

The new market equilibrium price P_t^{EE} after the conversion is similarly obtained from (5.8) and (5.10):

$$P_t^{EE} = (1-\theta)^{\eta\nu} P_0 e^{\mu\nu t} = (1-\theta)^{\eta\nu} \left[\frac{A(\theta)}{A_0}\right]^{\eta} P_t^E \tag{5.20}$$

Let $\tilde{P}_t^E$ denote the suppositional market price under no negative spillovers and no entry. Then it has to be

$$\tilde{P}_t^E = P_0 e^{\mu\nu t} = \left[\frac{A(\theta)}{A_0}\right]^{\eta} P_t^E \tag{5.21}$$

(5.21) implies that the price fall by the factor $[A(\theta)/A_0]^{\eta}$ in (5.20) represents the effect of the removal of the negative spillovers. Since P_t^{EE} is the price under the entry of the new firm in addition to the removal of the negative spillovers, the factor $(1-\theta)^{\eta\nu}$ in (5.20) represents the price decline caused by the production increase of the new firm.

Substituting (5.2) and (5.20) into (5.17) yields the change in consumer surplus

$$\Delta CS_t = \frac{P_t^E Q_t^E}{\sigma - 1}\left\{\left(\frac{1}{1-\theta}\right)^{1-\eta}\left[\frac{A_0}{A(\theta)}\right]^{\eta(\sigma-1)} - 1\right\} > 0$$

where $Q_t^E = Y_t P_t^{E^{-\sigma}}$ is the quantity in equilibrium without the conversion. Substituting (5.7), (5.19), and (5.20) into (5.18) yields

$$\Delta PS_t = \nu P_t^E Q_t^E \left\{\left(\frac{1}{1-\theta}\right)^{1-\eta}\left[\frac{A_0}{A(\theta)}\right]^{\eta(\sigma-1)} - 1\right\} > 0$$

The total social surplus change is the sum of the changes in consumer's surplus and producer's surplus, and is given by

$$\Delta SS_t = P_t^E Q_t^E \left(\nu + \frac{1}{\sigma-1}\right)\left\{\left(\frac{1}{1-\theta}\right)^{1-\eta}\left[\frac{A_0}{A(\theta)}\right]^{\eta(\sigma-1)} - 1\right\} > 0 \qquad (5.22)$$

But substituting (5.9) into (5.7) yields

$$Q_t^E = Q_0 \left[\frac{A(\theta)}{A_0}\right]^{\eta\sigma} e^{\mu(\alpha+\beta)t} \qquad (5.23)$$

Plugging (5.9) and (5.23) into (5.22) yields

$$\Delta SS_t = P_0 Q_0 \left(\nu + \frac{1}{\sigma-1}\right)\left\{\left(\frac{1}{1-\theta}\right)^{1-\eta} - \left[\frac{A(\theta)}{A_0}\right]^{\eta(\sigma-1)}\right\} e^{\mu t} > 0 \qquad (5.24)$$

Recall from the previous paper that the optimal factor employment condition in stationary equilibrium requires

$$r\bar{p}_L = \frac{\nu P_0 q_{i0}}{L_{iE}} \Rightarrow r\bar{p}_L = \frac{\nu P_0 Q_0}{L_E}$$

Using (5.1) and (5.24), the following is obtained

$$P_0Q_0 = \left(\frac{r\bar{p}_L}{\nu}\right)(1-\theta)L$$

Substituting this into (5.24) yields

$$\Delta SS_t = r\bar{p}_L L\left(1+\frac{1}{\nu(\sigma-1)}\right)(1-\theta)\left\{\left(\frac{1}{1-\theta}\right)^{1-\eta} - \left[\frac{A(\theta)}{A_0}\right]^{\eta(\sigma-1)}\right\}e^{\mu t} \tag{5.25}$$

When the firm converts the abandoned properties simultaneously at t_{Ne}^*, the present value of the total social surplus change, *G* is then

$$G = \int_{t_{Ne}^*}^{\infty} \Delta SS_t dt = \frac{r}{r-\mu}\left(1+\frac{1}{\nu(\sigma-1)}\right)\frac{1}{\theta}\left\{1-\left[(1-\theta)^{\eta\nu}\left[\frac{A(\theta)}{A_0}\right]^{\eta}\right]^{\sigma-1}\right\} \tag{5.26}$$

The term within the curly brackets represents the pecuniary externality per unit production caused by the conversion of the legacy property. From (5.20), one can see that the expression within the square brackets is the price ratio P_t^{EE}/P_t^E. The first factor is due to the production increase by the new firm and the second is due to the removal of the negative spillovers. The two effects increase with the share θ of the abandoned properties, that is, the two factors decrease with θ. The output price decline caused by the conversion leads to an increase in consumer surplus's and producer's surplus. That is the reason for the negative sign before the square brackets. Obviously, the value within the curly brackets increases with θ because a conversion of a large amount of abandoned properties leads to a large price change. But the expression within the curly brackets represents only the effect on unit production, and the whole pecuniary externality must take into account the whole amount of production affected by the price change, which is represented by the term $1/\theta$. As θ increases, the real externality per unit property increases but the size of total affected properties decreases. As a results, the net effect of the conversion decreases with θ in the beginning but rises again after a certain point.

5.5.2 Pigouvian Subsidy

While the conversion of legacy property raises social surplus, private firms do not take into account the full effect of the conversion. Hence, legacy property is converted too late and remains abandoned for too long. To achieve the socially optimal timing the government must intervene with appropriate policy instruments.

A Pigouvian subsidy for the conversion is a possible instrument to achieve the social optimum. The subsidy lowers the conversion cost for private commercial firms and thus advances the conversion time. Figure 5.2 illustrates the effect of a Pigouvian subsidy. The green solid line represents the actual market equilibrium in the commercial sector. It originally is $\tilde{Q}_t^E$, but drops to Q_t^E at t_f due to negative abandonment spillovers; it then jumps to Q_t^{EE} at the time of conversion t_e^*. The increase in the market supply, segment CD reflects gains from both the rise from productivity (segment CF) and the increase in production by the new firm (segment FD). A subsidy advances the conversion to tt_e^* and the jump in the market equilibrium occurs at the new conversion time. The red solid line represents the new equilibrium. As a result, the production changes by the amount of polygon ABCD. Polygon EBCF represents the increase from productivity gains, and polygon AEFD represents the increases from increased production by the new firm's entry.

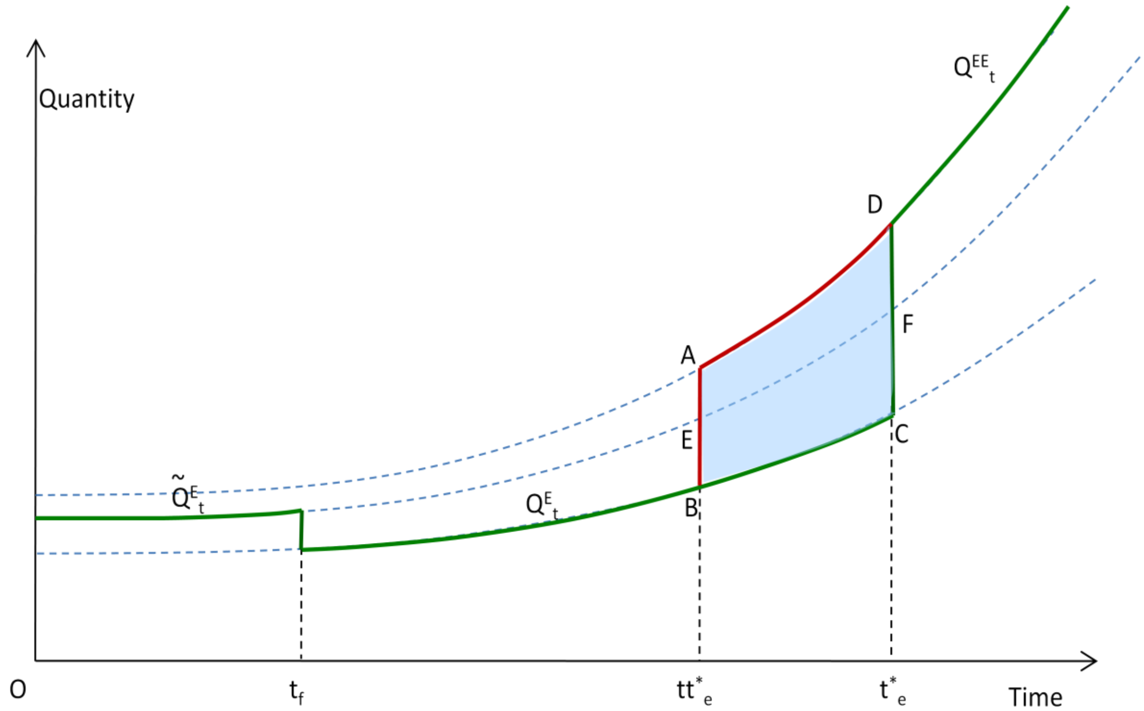

Figure 5.2: Subsidy and Production in Commercial Sector

The increase in social welfare due to the subsidy is measured by the present value of the increase in social surplus net of the subsidy, *NPVSS*. Formally,

$$NPVSS = \int_{tt_e^*}^{t_e^*} e^{-r(t-tt_e^*)} \Delta SS_t \, dt - S_P \tag{5.27}$$

where S_P is the amount of the Pigouvian subsidy. Substituting (5.25) into (5.27), and using $L = L_A/\theta$ yields

$$NPVSS = \frac{r\bar{p}_L L_A}{r-\mu}\left(1+\frac{1}{\nu(\sigma-1)}\right)\left(\frac{1-\theta}{\theta}\right)\left\{\left(\frac{1}{1-\theta}\right)^{1-\eta} - \left[\frac{A(\theta)}{A_0}\right]^{\eta(\sigma-1)}\right\}\left[e^{-(r-\mu)tt_e^*} - e^{-(r-\mu)t_e^*}\right]e^{rtt_e^*} - S_P \tag{5.28}$$

The new conversion time tt_e^* is readily computed as follow:

$$tt_e^* = \frac{1}{\mu}\log\frac{S - S_P}{\bar{p}_L L_A} + \frac{\eta}{\mu}\log\frac{1}{1-\theta} \tag{5.29}$$

Substituting t_{NE}^* in (5.15) for t_E^* in (5.28), and plugging (5.29) into (5.28) yields

$$NPVSS = G(S - S_P)\left[1 - \left(1 - \frac{S_P}{S}\right)^{\frac{r-\mu}{\mu}}\right] - S_P$$

where *G* is the present value of the total social surplus change due to the conversion in the market equilibrium as shown in (5.26). Obviously, *NPVSS* is a function of θ, because it is increasing in *G* and G is a function of θ. It is also a function of the subsidy, S_P.

The optimum level of the subsidy is derived by differentiating *NPVSS* with respect to S_P and equating it to zero. The result is

$$S_P^* = S\left\{1 - \left[\frac{\mu(G+1)}{rG}\right]^{\frac{\mu}{r-\mu}}\right\} \tag{5.30}$$

The optimal level of subsidy must be equal to marginal externality generated by the advanced conversion of abandoned properties, which is a matter of course with Pigouvian taxation. This can be rewritten to obtain the optimal Pigouvian subsidy percentage as follows:

$$\frac{S_P^*}{S} = 1 - \left[\frac{\mu(G+1)}{rG}\right]^{\frac{\mu}{r-\mu}}$$

S_P^*/S is increasing in *G* and thus they behave in the same direction when the parameters vary. Since *G* is decreasing in $A(\theta)$ for a given θ, S_P^*/S should increase as $A(\theta)$ decreases, that is, as the negative spillovers become large. However, the productivity $A(\theta)$ is usually a function of θ and hence S_P^*/S should also be a function of θ. Just as *G* does, the optimal percentage should decrease with θ in the beginning but rises again after a certain point. It turns out that, however, S_P^*/S does not much depend on the value of θ, because $(G+1)/G \approx 1$ for reasonable values of the parameters regardless of the value of θ. S_P^*/S can be approximated by

$$\frac{S_P^*}{S} \approx 1 - \left(\frac{\mu}{r}\right)^{\frac{\mu/r}{1-\mu/r}}$$

Note that it is an increasing function of only one variable μ/r, the growth rate of the remaining sector relative to the interest rate. Since the argument can vary between 0 and 1, the function has a value between 0 and $1 - 1/e \cong 0.632$. So the optimal Pigouvian subsidy cannot exceed around 63 per cent of the conversion cost. Since S_P^*/S is increasing in μ/r, the subsidy level has to increase with the growth rate with no subsidy for zero growth rate.

The socially optimal conversion time can be derived by substituting (5.30) into (5.29),

$$\begin{aligned} tt_e^* &= \frac{1}{\mu}\log\frac{S}{\bar{p}_L L_A} + \frac{\eta}{\mu}\log\frac{1}{1-\theta} - \frac{1}{r-\mu}\log\frac{rG}{\mu(G+1)} \\ &= t_{Ne}^* - \frac{1}{r-\mu}\log\frac{rG}{\mu(G+1)} \end{aligned}$$

In other words, the conversion time should be advanced from the conversion time in market equilibrium by $(1/r-\mu)\log[rG/\mu(G+1)]$. Then the net present value of the subsidy is given by

$$NPVSS^* = S\left\{\frac{r-\mu}{r}(G+1)\left[\frac{\mu(G+1)}{rG}\right]^{\frac{\mu}{r-\mu}} - 1\right\}$$

5.6 Concluding remarks

This paper has dealt with the conversion of abandoned properties that have negative spillovers on the remaining firms. The conversion creates two types of positive externalities, a real externality and a pecuniary externality. Neither externality is considered by private agents when they decide on a conversion. Hence the conversion tends to occur too late, relative to the social optimum. The conversion process depends on the fragmentation status of abandoned properties. The paper suggests that one-shot development occurs earlier than fragmented conversion when negative real spillovers are very large. The paper also suggests ways to achieve the social optimum. The conversion cost should be subsidized in an amount equal to marginal externality generated by the advanced conversion of abandoned properties. The optimal level of subsidy depends largely on the growth rate of the remaining sector relative to the interest rate.

The optimal subsidy is derived for the case of one-shot conversion, though the model can also be applied to find the optimal subsidy for the case of fragmented conversion. This requires numerical simulation to describe the fragmented conversion process using (i) a stylized function of negative spillover $A(\theta)$ and (ii) a conversion cost function $S(L_{jA})$. With these assumptions, an optimal subsidy level can be computed numerically, and the optimal choice between fragmented and one-shot conversion can be made as well. The details are reserved for a future work.

I have also alluded to several model extensions. While the entire model was phrased in terms of abandonment, I argued in the introduction that the model can be reformulated in terms of suburban and edge city development decisions. As in the case of abandonment, so in this case, development timing is an important consideration. Specifically, I hypothesize that the model will be able to provide another justification for sprawl and leapfrogging. For a single developer to develop an edge city, it must beat out potentially earlier fragmented individual decision makers. This is a matter of timing and the location of land assembly sufficiently far away from ongoing individual property development, to allow the edge city developer to internalize a large share of otherwise external benefits.

Chapter 6: Urban Decline, Legacy Capital, and City Size in the U.S.

6.1 Introduction

Over the last 50 years, many cities in the U.S. have experienced prolonged periods of urban decline, often as a result of external shocks that severely disrupted their economic base. However, some cities have succeeded in reversing direction, while others have not. This chapter looks at reasons for the difference. Specifically, it relates the difference in population growth to the difference in cities' assets.

Two key assets of a city are introduced to explain the difference: Legacy capital and agglomeration economies. Even after firms and their employees move out of a city, legacy capital such as buildings and infrastructure remain, with both positive and negative impacts on growth and productivity. Some legacy capital can be readily switched into another use, while other legacy capital needs much time and cost for switching. Hence the composition of legacy capital may have an impact on the path of urban growth and decline. Agglomeration economies also impact urban decline by influencing firms' productivity and inhabitants' utility. Agglomeration economies also become a legacy in the sense that business environment and urban amenities last a long time, once created. Therefore, they can mitigate the process of decline.

This chapter aims to survey how legacy capital and agglomeration economies impact cities during periods of decline. For this purpose, we first look at how urban decline is influenced by the inertia of growth. Second, differences in the adjustment to decline of different types of legacy capital—offices and industrial properties—are dealt with in relation to its impact on urban growth/decline. Third, the impact of agglomeration economies is incorporated into the model.

6.2 Theory and Hypotheses

6.2.1 Theory on Path Dependence of Growth

Urban growth and decline has long been a topic of research, stimulated by the decline of industrial cities starting in the 1960s and the growth of mining boom towns in the 1970s. That research has also been facilitated by theoretical advances in urban economics such as dynamic optimization theories since the early 1970s (von Rabenau, 1976). While many studies have looked at the causes of decline, few have analyzed the impact of cities' assets on the different paths of decline. Recent years have seen the growing literature dealing with the path dependency of urban growth that suggests current and future change depends on actions taken in the past (Anas, Arnott, & Small, 1998; Martin & Sunley, 2006). This study is part of such literature. Some researchers such as Krugman (1991a), Glaeser and Gyourko (2005) have linked growth/decline to the durability of production infrastructure or housing but their research did not deal with the adjustment of legacies. The significance of my research lies in the novelty of its topics and verification method, and its policy implications.

First, this section argues that urban decline varies with the nature of legacy capital. The less reversible an investment, the more difficult or costly the re-use of capital, and the lower the capacity of demand to absorb legacy capital, the greater is the impact on urban decline.

Much legacy capital such as buildings and infrastructure is immobile, and hence it remains even after firms and their employees have moved out. Lack of mobility means that its price drops until eventually it can be re-used by other firms. Re-use at a lower price saves firms' production costs and the economy declines less than it might have otherwise. Re-use of capital however, is not without transaction costs such as switching and conversion cost. Switching to new uses may take time as sellers search for possible buyers and adjust their expectations.

Given these type of costs, investment theory suggests delays in capital reuse (Abel & Eberly, 1999). The likelihood that capital remains idle is the higher, the greater the cost of switching and the less diversified the industrial mix. Specialized economies will have greater difficulties absorbing capital from a departing sector.

Idleness will also be impacted by capital specialization. Some industries rely on capital that is highly specialized and has few alternative uses, while other industries use mainly a type of capital used across a broad spectrum of industries. Services, finance, and public administration all use office space with similar attributes. Instead, manufacturing industries have widely different capital needs, even when one considers only their buildings. The result is that an urban area's industrial composition matters. For instance, the decline of a town specialized in the steel industry will be more persistent than one that specializes in the service sector. Capital will tend to be idle longer, and adverse consequences for urban growth will be greater.

Second, we also pay attention to agglomeration economies as another form of asset that can impact the process of decline. As seen in Chapter 2, agglomeration effects in large cities have positive or negative impacts both on production and consumption (Tabuchi & Yoshida, 2000). On the production side, the agglomeration of economic activities creates a favorable environment for firms, which leads to an increase in their productivity. Abundant labor pooling, large home markets, and rich non-traded inputs such as urban infrastructure in an agglomerated region improve the productivity of firms by reducing production costs (Krugman, 1991b). Of course, some diseconomies such as congestion offset the productivity gains for firms. On the consumption side, individuals who live in an agglomerated region can also be affected by the (dis)amenities formed in that region. Amenity gains for individual consumers are the results of great product variety and good urban infrastructure, while amenity losses come from crime, congestion, and high cost of living. Provided that agglomeration (dis)economies linger following an external shock, they impact the location decisions of the remaining and outside firms as well as individuals' choice of central city or suburb as place of residence. Consequently, they can influence the path of urban decline.

Recently, the impact on the consumption side has become more important, as the demand for urban amenities has been rising while firms' productivity gains have slowed. Indeed, some researchers argue that amenity gains today drive the resurgence of large U.S. cities (Glaeser, Kolko, & Saiz, 2001; Glaeser & Gottlieb, 2006). If a large city on the decline still retains large amenities such as good public services, product variety, and diverse social interaction, it can arguably resurge from decline as a "consumption city." Moreover, as people's preferences for urban amenities become stronger with higher incomes, good urban amenities can decelerate the speed of urban decline by attracting new inhabitants. Since urban amenities such as museums, restaurants, and live performance venue are normal goods or luxury goods, their demand becomes larger as people's income increases. Of course, there may be offsetting disamenities, and hence the net effect on urban decline is determined by the magnitude of positive and negative agglomeration effects.

It is an empirical question whether the net effect on urban growth/decline of agglomeration economies is positive or negative. Since population size can be used as a proxy of agglomeration (dis)economies, we can measure the net effect by incorporating it into an empirical model of urban growth/decline.

6.2.2 Research Hypotheses

Based on the above theory, we derive three research questions and hypotheses to be tested empirically against historical data.

The first question is about the asymmetry between cities' growth and decline. Provided that a city's decline is impacted by its path of growth, the path of growth and decline is asymmetric. Since the legacy of past growth may retard the rate of decline, one can expect that the gradient of decline with respect to external shocks should be less steep than its growth counterpart.

The second question is about the impact on growth of legacy capital. Given that legacy capital may impact the path of growth, one can directly test whether reuse of legacy capital raises the rate of growth. Also, one may have a question about differences between industrial and commercial capital. We hypothesize that the impact on growth of reuse of legacy capital would be positive and the impact is more significant with industrial capital than commercial capital, as abandoned industrial capital has larger externalities. A related hypothesis is that the stock of abandoned capital retards growth. The relative size of this stock may be measured by the vacancy rate, though it does not include abandoned capital, and hence we lack the data to fully test this hypothesis.

The third question is about the impact on growth of agglomeration economies. Given that agglomeration economies impact firms' productivity and consumers' quality of life, one can directly test the impact as with legacy capital. Of course, once the system of regions reaches a long-term equilibrium (usually assumed in the literature as in Chapter 2), agglomeration economies no longer can impact urban dynamics. But if there is an external shock, then growth or decline become again part of the adjustment process to a new equilibrium. We test, for the period 1990-2000, whether and how agglomeration size impacts growth. In principle, Chapter 2 has shown that amenity impacts can be negative while productivity impacts tend to be positive (with impacts in the housing sector negative but of very small size). Hence, the sign is ambiguous.

6.3 Measures and Data

Since this study deals with several elusive concepts such as urban decline/growth, legacy capital, agglomeration economies, and external shocks, we need to define the measures for those major variables. First, the growth and decline of a city is defined in terms of population change over the 10 years between 1990 and 2000. Since this measure is the most widely used for growth in the literature, and data is readily available, we follow the convention. Second, legacy capital examined in this study is two types of capital: offices and industrial properties. The latter includes manufacturing plants, warehouses, and high-tech/R&D properties. Reuse of legacy capital is measured by the net absorption rate of those properties. Third, agglomeration economies are measured by a proxy of city size only as in the literature. As seen in Chapter 2, it is better for the model to include individual agglomeration factors separately. But data availability restriction makes this study use the conventional measure for this survey. Fourth, an external shock is measured by the 10-year growth in jobs.

The data set is constructed for the central cities of Metropolitan Statistical Areas (MSA) in the U.S. using the Census data, the State of the Cities Data Systems (SOCDS), and the Society of Industrial and Office Realtors' (SIOR) data set, *Comparative Statistics of Industrial and Office Real Estate Markets*. The cities in the sample are the central cities of all the 326 MSAs whose information is provided by SOCDS. When two or more central cities are identified for an MSA, the data are aggregated. Of the 326 MSA regions, 95 (29 percent) MSAs have declining central cities, and 231 (71 percent) MSAs have growing central cities for the period 1990 – 2000. Central cities also range widely in size, from a minimum of 11,182 (Benton Harbor, MI) to 8,061,355 (New York City, NY).

As SIOR's data do not cover all 326 MSAs and many data are missing, we extract a sample of central cities in 36 MSAs,[35] for which data are available on office and industrial property markets for 1991 and 2001. For the sample cities, the range of population size for 2000 is 86,605 (Nashua City, NH) to 2,896,016 (Chicago City, IL), and the average is about 560,000. This sample includes 10 (28 percent) declining central cities, and 26 (72 percent) growing central cities for the period 1990 – 2000. This sampling reflects the distribution of growth groups for the 326 MSA regions. The sources of data and the definitions of variables are summarized in Appendix E, and the descriptive statistics for the variables are reported in Appendix F.

6.4 Empirical Findings

6.4.1 Asymmetry of growth and decline

The first implication of the theory is that the path of urban growth and decline is asymmetric because urban decline is influenced by the legacy of past growth. Given that tangible and intangible legacies such as legacy capital and agglomeration economies influence the path of decline, the gradient of decline with respect to external shocks should be less steep than its growth counterpart.

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[35] All the 36 MSAs have only one central city except one MSA–Minneapolis/St.Paul, MN. Data for the central cities within a metropolitan area are aggregated into one set.

We regress the population percent change (*popgrwth*) on the piecewise job percent change to determine how the impact of job change differs between growing and declining cities as follows:

$$popgrwth = \alpha_0 + \alpha_1 jobgw + \alpha_2 jobdcl + \varepsilon_1 \quad (6.1)$$

where *jobgw* is the job growth rate for the 10 year period 1990-2000 if greater than zero, and zero if smaller than zero; *jobdcl* is the Job growth rate for the same period if smaller than zero, and zero if greater than zero; and α's are parameters; and ε_1 is the error term. The equation is estimated using OLS with Census data for the central cities of all the 326 MSAs with identified central cities. The full results of regression are reported in Table 6.1.

Dependent Variable: *popgrwth*				
Variable	Par. Estimate	Std. Error	t Value	Pr > |t|
jobgw	0.84627	0.05368	15.77	<.0001
jobdcl	0.3665	0.14602	2.51	0.0126
constant	0.01518	0.01217	1.25	0.2133
Observations	326		F(2,323)	164.07
R-Square	0.504		Adj R-Sq	0.5009

Table 6.1: Regression results for the asymmetry model

The regression results tell us that the coefficient of the Job growth rate is 0.846 during the periods of growth but it is only 0.366 during the periods of decline. The test for the null hypothesis of the two coefficients being equal shows that they are significantly different (F-value of 7.68; p-value of 0.0059). In other words, one percentage point of job losses has a smaller effect on population change than a one percentage point of job gains.[36]

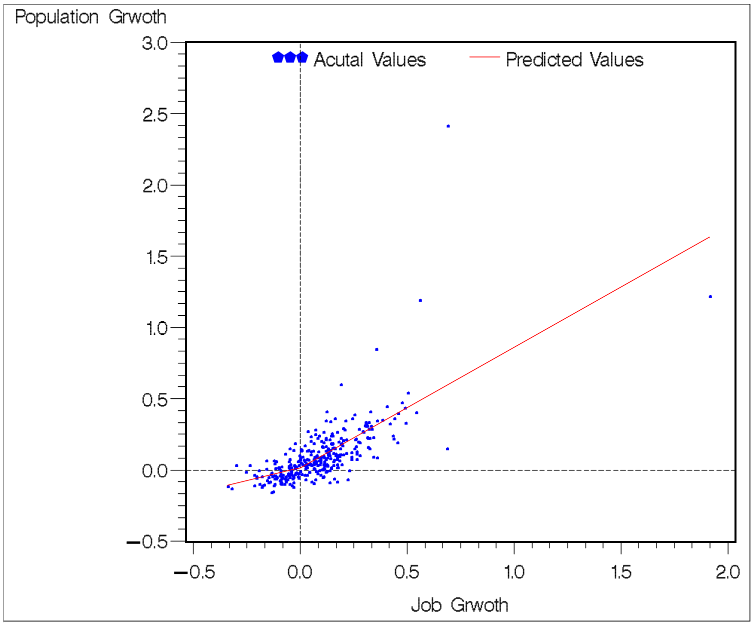

Figure 6.1: Asymmetry between Growth and Decline of Cities

Figure 6.1 plots the relationship between job growth and population growth in the 1990s for the central cities of the 326 MSAs. The dots represent the actual values and the line represents the predicted values by (6.1). It also shows this asymmetry of urban growth and decline. The growth gradient for declining cities is less steep than that for growing cities.

[36] We should not interpret the coefficients of Eq. (1) as the accurate effect of job change on population change, as the estimates are biased because of possible endogeneity of the regressors. None the less, the estimates certainly show that the gradient of decline is less steep than that of growth.

Alternatively, the asymmetry between growth and decline can be shown through the ratio of population-to-jobs. If population slowly responds to a negative external shock, as measured by job growth, the population-to-jobs ratio has to increase in cities with shrinking jobs. Conversely, the ratio has to stay constant in cities with growing jobs, as population quickly responds to a positive shock. To confirm this, we regress the population-to-jobs ratio for the year 2000 (*pop*2*job*00) on the ratio for the year 1990. The 1990 ratio is defined piecewise as in (6.1) to distinguish the effect between cities with positive shocks and negative shocks. So the regression equation is

$$pop2job00 = \beta_0 + \beta_1 p2j90gw + \beta_2 p2j90dcl + \varepsilon_2$$

where $p2j90gw$ is the population to job ratio for the year 1990 if greater than zero, and zero if smaller than zero; $p2j90dcl$ is the 1990 ratio if smaller than zero, and zero if greater than zero; β's are parameters; and ε_2 is the error term. Of course, since there may be interference from changes in the unemployment rate and/or labor force participation rate, we do the same analysis with the employed worker-to-job ratio (emp2job) over the same time horizon. In other words, the following regression is also used

$$emp2job00 = \beta_0' + \beta_1' e2j90gw + \beta_2' e2j90dcl + \varepsilon_2'$$

where $e2j90gw$ is the employed worker to job ratio for the year 1990 if greater than zero, and zero if smaller than zero; $e2j90dcl$ is the 1990 ratio if smaller than zero, and zero if greater than zero; β' 's are parameters; and ε'_2 is the error term. The OLS estimation results are reported in Table 6.2.

Dependent Variable: *pop2job*00				
Variable	Par. Estimate	Std. Error	t Value	Pr > |t|
p2j90gw	0.98742	0.00693	142.42	<.0001
p2j90dcl	1.08349	0.01014	106.9	<.0001
Observations	326		F(2,324)	15856.3
R-Square	0.9899		Adj R-Sq	0.9898
Dependent Variable: *emp2job00*				
Variable	Par. Estimate	Std. Error	t Value	Pr > |t|
e2j90gw	0.99112	0.00618	160.29	<.0001
e2j90dcl	1.06314	0.00959	110.81	<.0001
Observations	326		F(2,324)	18986.2
R-Square	0.9915		Adj R-Sq	0.9915

Table 6.2: Regression results for population-to-job and employed worker-to-job ratios

We test the null hypothesis that all the coefficients are equal to unity. The F-test results are summarized in Table 6.3. The results show that the population-to-job ratio and the employed worker-to-job ratio stay the same in cities with growing jobs over the 10 years, but that the two ratios have significantly increased in cities with shrinking jobs during the same time period.

H0 (Null)	F Value	Pr > F	Test Result
$\beta_1 = 1$	3.29	0.0705	Accept ($\beta_1 = 1$)
$\beta_2 = 1$	67.86	<.0001	Reject ($\beta_2 > 1$)
$\beta'_1 = 1$	2.06	0.1519	Accept ($\beta'_1 = 1$)
$\beta'_2 = 1$	43.31	<.0001	Reject ($\beta'_2 > 1$)

Table 6.3: Test results for increasing population-to-job and employed worker-to-job ratios

Our interpretation is that the inertia of growth makes the path of decline less steep than that of growth. Even if the number of jobs declines, legacy capital and agglomeration economies in consumption slow population decline. As a result, job losses do not lead to similar population losses. This result is similar to the argument on the asymmetry between growth and decline made by Glaeser and Gyourko (2005) related to the durability of housing and the speed of stock adjustments during periods of growth and decline.

When jobs expand, housing is supplied quickly to accommodate new workers and thus population grows almost at the same speed as the rate of job growth. When jobs shrink, however, the lack of demand for existing housing stock reduces housing prices, inhibiting job mobility, and reducing the population response to job losses. This is reinforced by remaining consumption opportunities from the effects of other legacy capital, such as durable infrastructure and recreational opportunities. In a nutshell, our results suggest that the consumption center function of central cities has become more important during the 1990s.

6.4.2 Impact on urban growth/decline of legacy capital

This section tests a hypothesis related to the impact of legacy capital on city growth/decline. Theory tells us that legacy capital may contribute to city growth by being reused as cheap input for the remaining firms.[37] The presence of legacy capital increases the supply of capital of its kind and raises the availability (vacancy) of the capital in the market. If this higher availability is utilized by the remaining firms, then the city will grow faster than it would otherwise. The following regression results verify this implication.

[37] Abandoned legacy capital has negative spillovers on the surrounding neighborhood and hence a negative effect on population growth. Since we do not have data on the abandonment of legacy capital, however, the current model doe not take into account this effect.

We regress population growth on the vacancies of the two types of capital, office and industrial property, and the net absorption to vacancy ratios for the two types of capital in 1991 as follows:

$$
\begin{aligned}
popgrwth = \gamma_0 + \gamma_1 indvac91 + \gamma_2 indabs91 + \gamma_3 offvac91 \\
+ \gamma_4 cbdoffabs91 + \gamma_5 outoffabs91 \\
+ \gamma_6 mfgshr90 + \varepsilon_3
\end{aligned}
\tag{6.2}
$$

where *indvac*91 is the vacancy rate of industrial properties in a city in 1991; *indabs*91 is the ratio of the net absorption during the 1990-1991 period to vacancy in 1991 for industrial properties; *offvac*91 is the vacancy rate of offices in 1991; *cbdoffabs*91 and *outoffabs*91 are the ratios of the net absorption during the 1990-1991 period to vacancy in 1991 for offices inside and outside the CBD, respectively; *mfgshr*90 is the employment share of the manufacturing sector; and γ's are parameters; and ε_3 is the error term. Note that the employment share of the manufacturing sector is included to control for the effect of industry mix. In general, one would expect that cities with a large industrial base would experience less growth than cities with a non-industrial base. This is so because of a long trail of evidence suggesting that the share of industrial employment declines over time in industrialized countries. Cities with a higher share of industrial employment simply share the national decline of manufacturing. Once this effect is controlled for, the pure effect of the availability and absorption of capital can be determined. The equation is estimated using OLS with the SIOR and Census data for 36 central cities for which all the property data are available. The full results of regression are reported in Table 6.4.

Dependent Variable: *popgrwth*				
Variable	Par. Estimate	Std. Error	t Value	Pr > |t|
*indvac*91	0.42392	0.24689	1.72	0.0966
*indabs*91	0.19227	0.0685	2.81	0.0089
*offcvac*91	0.32024	0.45123	0.71	0.4836
*cbdoffabs*91	0.1118	0.11347	0.99	0.3326
*outoffabs*91	-0.17988	0.09075	-1.98	0.057
*mfgshr*90	-0.79532	0.26897	-2.96	0.0061
constnat	0.05577	0.09917	0.56	0.5782
Observations	36		F(6, 29)	4.27
R-Square	0.4689		Adj R-Sq	0.359

Table 6.4: Regression results of the legacy capital model

The results tell us that, for industrial properties, a high availability and reuse of capital leads to a significantly high population growth, while for offices only the absorption of capital has a significantly positive effect. As discussed in Chapters 3 and 4, we would expect a high abandonment rate of industrial properties to impede growth. However, this is not tested due to a lack of data.

First, look at the effects of industrial properties. A one percentage point increase in the initial vacancy rate of industrial properties leads to 0.42 percentage point increase in population growth over the following 10 years. This is a bit surprising as theory suggests that negative spillovers from capital abandonment create a drag on the local economy and hence, lead to population decline rather than growth. But the vacancy rate omits abandoned properties, and hence is not a good indicator of abandonment. Also, a high industrial vacancy rate is often consistent with a small industrial employment share, so that industrial decline will have little impact.

The results also show that a 10 percentage point increase in the net absorption to vacancy ratio for industrial properties in the initial year leads to a 1.9 percentage point increase in population growth. This is completely in line with the theoretical prediction that reuse of legacy capital contribute to a city's growth.

Second, look at the effects of offices. The effect of the initial vacancy rate of offices is not significant, though it shows a positive tendency. The estimation results imply that a high absorption of offices outside the CBD has a negative effect on population growth of the central city, while the absorption of offices in the CBD has no significant effect. A 10 percentage point increase in the net absorption to vacancy ratio for offices outside the CBD in the initial year leads to a 1.8 percentage point decrease in population growth. A high absorption rate outside the CBD means that many businesses are created or expanded outside the CBD, which induces migration of city residents into suburbs. Hence such a negative effect on population growth makes sense.

In short, the regression results suggest that the availability and absorption of industrial properties was more critical to population growth in the 10-year period 1990-2000 than that of offices. There are several reasons: First, consider availability. The inflexible supply of industrial properties makes their availability more important than the availability of offices. Industrial properties are not as easy to produce as offices and thus their supply is not as flexible as the supply of offices. So a long term change such as population growth is more affected by the availability of the first than that of the latter. Second, consider absorption of industrial properties. It has a positive effect because it eliminates capital stock that otherwise might have generated negative spillovers. It also is an indicator of demand from other industrial firms (as most industrial property is absorbed by other industrial users). This demand is sustained, as the high cost of entry in the manufacturing sector makes it likely that the effect from such entry at the beginning of the 10-year period would persist throughout the period. The cost of entry in the industrial sector is high because new properties are costly to develop, and existing properties are costly to convert to new uses.

6.4.3 Impact of agglomeration economies

This section investigates whether agglomeration (dis)economies have a positive or negative effect on population growth. Theory suggests that the sign is ambiguous as the size of an agglomeration can have both positive and negative effects on individuals' utility and firms' productivity.

We add to (6.1) the logarithm of the 1990 population size as a proxy of agglomeration economies to see its effect on growth as follows:

$$popgrwth = \delta_0 + \delta_1 jobgw + \delta_2 jobdcl + \delta_3 \log(pop90) + \varepsilon_4 \quad (6.3)$$

where *pop*90 is the population of a central city in 1990; δ's are parameters; and ε_4 is the error term. The model is estimated using OLS with Census data for the central cities of all the 326 MSAs. The full results of regression are reported in Table 6.5.

Dependent Variable: *popgrwth*				
Variable	Par. Estimate	Std. Error	t Value	Pr > |t|
jobgw	0.86637	0.05268	16.45	<.0001
jobdcl	0.28476	0.14407	1.98	0.0489
log(*pop*90)	0.03148	0.00777	4.05	<.0001
Constant	-0.36025	0.0934	-3.86	0.0001
Observations	326		F(3, 322)	120.08
R-Square	0.528		Adj R-Sq	0.5236

Table 6.5: Regression results of the city size model

The estimation results tell us that larger cities experienced faster population growth over the 10 year period of 1990-2000. Suppose that a central city had twice larger population than another city in 1990 and they experienced the same external shock, as measured by job growth in the following 10 years. The estimated model suggests that the larger city experienced 3.1 percentage point faster population growth than the smaller city in the 10 year period. This suggests that size is rewarded, and that for equal job growth, central cities tend towards increasing size inequality, as larger cities experience higher growth rates than smaller cities. It is difficult to see however, how this result could be sustainable in the long term, given that central cities almost never have room to expand in physical size. Rather, this result shows the particular phenomenon for the 1990s in the U.S. Further, it does not necessarily mean that larger cities grow faster than smaller cities, as the population growth rate is more strongly determined by the rate of job growth.

A plausible interpretation is that the traditional aversion of large central cities since the 1960s began to reverse in the 1990s in the U.S. It seems that this was a result of either global immigration from foreign countries to large U.S. cities or people's strengthened preference for amenities associated with city size, or both. The identification of the exact cause requires further research. In any case, recent successes of some large central cities such as Chicago in reversing their decline can be seen as being confirmed by these results.

6.5 Conclusion

Urban decline is a process influenced by the legacies of past growth. Focusing on legacy capital and agglomeration economies as two forms of this legacy, we find that the inertia of past growth impacts the process of decline. A negative external shock does not give rise to as steep a change as a positive external shock.

Differences in a city's legacy impact its path of decline. Since different types of legacy capital offer different opportunities for re-use and transfer to alternative uses, they have a different impact on a city's decline. Specifically, industrial properties are more difficult to transfer into new uses than offices, and thus cities with a high share of such properties are likely to suffer a steeper decline even with the industry mix controlled for. We also confirmed that the effect on urban growth of agglomeration economies depends largely on population size. This implies that the inertia of growth in the phase of decline is larger for large cities than for small cities.

Local and state governments have an important role to play in reversing urban decline. The paper suggests that the instruments should depend on the nature of capital freed by departing sectors, and that the focus must be on facilitating the absorption of idle capital into remaining sectors. Government may be able to reduce the cost of switching and re-use, it may assume some of the risks associated with the reuse of legacy capital such as brownfields, or it may be able to engage in public private partnerships that facilitate reuse. Many of these instruments are already in use, though their relative effectiveness in different situations is still not well established.

In a large city, the local government may take advantage of agglomeration economies to mitigate decline, either through productivity gains that attract firms or through utility gains that compensate people for the high cost of living. These separate effects of agglomeration economies however, have not been estimated here, but were discussed in Chapter 2.

Appendix A: Derivation for Agglomeration Economies Model

Consumers' Utility

The representative consumer's indirect utility function is written as

$$V\big(p_g, hpric, inc, ctax\big)$$
$$= A(\mathbf{s},\mathbf{q})pop^{a_1}\left(\frac{\theta}{p_g}\right)^{\theta}\left(\frac{1-\theta}{hpric}\right)^{1-\theta}(inc - ctax)$$

where p_g is the unit price of the traded composite. The open region assumption suggests that p_g should be constant across regions. So one can normalize its unit so that the unit price of the composite good is unity, that, is $p_g = 1$ as in (2.2). Using this and the spatial equilibrium assumption as in (2.1), one can get

$$A(\mathbf{s},\mathbf{q})pop^{a_1}\theta^{\theta}\left(\frac{1-\theta}{hpric}\right)^{1-\theta}(inc - ctax) = k$$

Taking the logarithm of both sides and letting the constant terms be a_0 yields

$$\log(pop) = a_0 - \frac{1}{a_1}\log(inc) - \frac{1}{a_1}\log\left(1 - \frac{ctax}{inc}\right)$$
$$+ \frac{1-\theta}{a_1}\log(hpric) - \frac{1}{a_1}\log\big(A(\mathbf{s},\mathbf{q})\big)$$

with $a_0 = (1/a_1)[\log(k) - \theta\log(\theta) - (1-\theta)\log(1-\theta)]$. But since $\log(1-x) \approx -x$ for a small value of $x << 1$, this can be rewritten as (2.9).

Production in the Traded Good Sector

The first order condition is derived from the profit maximization problem with the production function (2.4) for the representative firm in the traded good sector:

$$\frac{F(\mathbf{s},\mathbf{q})pop^{b_1}}{1+trtxrt} = \left(\frac{indr}{\alpha_1}\right)^{\alpha_1}\left(\frac{wag}{\beta_1}\right)^{\beta_1}\left(\frac{p_K}{\gamma_1}\right)^{\gamma_1} \tag{A.1}$$

The right hand side is the factor price index for the sector with a Cobb-Douglas production function. As explained in reference to (2.7), the right hand side also represents the regional income coming from the traded good sector for a given factor endowment. As we have assumed that all the population has the same factor endowment, the index in fact represents per capita income coming from that sector for a region. Since per capita income consists of the two incomes from the two sectors, a doubling of this index does not lead to a doubled per capita income. Let the share of per capita income coming from the traded good sector be ϕ. One can roughly say that per capita income in a region increases with an elasticity of ϕ with respect to this index. This relationship can be formalized as

$$cnvf_1\left[\left(\frac{indr}{\alpha_1}\right)^{\alpha_1}\left(\frac{wag}{\beta_1}\right)^{\beta_1}\left(\frac{p_K}{\gamma_1}\right)^{\gamma_1}\right]^{\phi} = inc \tag{A.2}$$

where $cnvf_1$ is a constant factor for converting the factor price index to per capita income. Substituting (A.1) for the factor price index in (A.2) and taking the logarithm of both sides yields

$$\log(inc) = b_0 + b_1\phi\log(pop) + \phi\log\left(F(\mathbf{z_{-1}})\right)$$
$$-\phi\log(1+trtxrt)$$

with $b_0 = \log(cnvf_1)$. But since since log (1+ x) ≈ x for a small value of x << 1, this can be rewritten as (2.10)

Production in the Housing Sector

Just as for the firm in the traded good sector, the first order condition of the profit maximization problem is derived from the production function (2.5) for the representative housing firm:

$$\frac{H(\mathbf{s},\mathbf{q})pop^{c_1}hpric}{1+hstxrt} = \left(\frac{resr}{\alpha_2}\right)^{\alpha_2}\left(\frac{wag}{\beta_2}\right)^{\beta_2}\left(\frac{p_K}{\gamma_2}\right)^{\gamma_2} \tag{A.3}$$

Since wage is the only income component varying across regions, the wage rate variable can be expressed as a function of per capita income. Let the income share of wages be ϖ. Then one can say that per capita income increases with an elasticity of ϖ with respect to the wage rate, as the other income components stay almost the same. Formally, it is written as

$$inc = cnvf_2 \cdot wag^{\varpi} \tag{A.4}$$

where $cnvf_2$ is a constant factor for converting the wage rate to per capita income. Note that this equation would be equivalent to (A.2) because $\varpi = \beta_1$ when the traded good sector occupies almost the whole economy, i.e. $\phi \approx 1$. Substituting (A.4) for the wage variable in (A.3) and taking the logarithm of both sides yields

$$\log(hpric) = d_0 + \alpha_2 \log(resr) + \frac{\beta_2}{\varpi}\log(inc) - c_1 \log(pop) + \log(1+hstxrt) - \log\big(H(\mathbf{s},\mathbf{q})\big) \tag{A.5}$$

with $d_0 = -(\beta_2/\varpi)\log(cnvf_2) + \gamma_2 \log(p_K) - \alpha_2 \log(\alpha_2) - \beta_2 \log(\beta_2) - \gamma_2 \log(\gamma_2)$ and $\alpha_2 + \beta_2 + \gamma_2 = 1$.

The unit-cost of housing production can be expressed as land rent and the amount of land per housing as follows:

$$hpric = \frac{resr \cdot l_y}{\alpha_2} \tag{A.6}$$

where l_y is land input per housing. Let $qhous$ and $arhous$ denote the total amount of housing and total area of residential land in a region. Then, the unit land input can be written as

$$l_y = \frac{arhous}{qhous} = \frac{1}{hden} \cong \frac{1}{pden} \cong \frac{area}{pop} \tag{A.7}$$

where *area* is the total land area of the region, and *hden* and *pden* denote housing density and population density in the region. In (A.7), housing density is approximated by population density. Using (A.6) and (A.7), land rent can be approximated by

$$resr \cong \alpha_2 hpric \frac{pop}{area} \tag{A.8}$$

Substituting (A.8) into (A.5) yields

$$\log(hpric) \cong c_0 + \frac{\beta_2}{(1-\alpha_2)\varpi}\log(inc) + \frac{\alpha_2 - c_1}{1-\alpha_2}\log(pop) - \frac{\alpha_2}{1-\alpha_2}\log(area)$$
$$+ \frac{1}{1-\alpha_2}\log(1 + hstxrt) - \frac{1}{1-\alpha_2}\log\big(H(\mathbf{s},\mathbf{q})\big)$$

with $c_0 = (d_0 + \alpha_2 \log \alpha_2)/(1-\alpha_2)$. But since log (1+ x) ≈ x for a small value of $x \ll 1$, this can be rewritten as (2.11)

Appendix B: Interpretation of Spatial Autoregressive Models

Own Effects and Neighborhood Effects

Here we introduce the interpretation method suggested by LeSage and Pace (2008; 2009) and suggest a variant, the average first order neighborhood effect (A1NEF) with the derivation of its computation. For exposition, rewrite the data generating process introduced in (2.26):

$$\mathbf{y} = \lambda \mathbf{W}\mathbf{y} + \mathbf{X}\boldsymbol{\beta} + \boldsymbol{\iota}_n \alpha + \boldsymbol{\varepsilon}$$

For this model, LeSage and Pace suggest three different effects: average direct effect (ADE), average total effect (ATE), and average indirect/neighborhood effect (ANE).

First, ADE is the average of own effects on the dependent variable of a change of an explanatory variable in an observation unit. Formally, the ADE for the r^{th} explanatory variable is defined as

$$ADE_r = \frac{1}{n}\sum_{i=1}^{n} \frac{\partial y_i}{\partial x_{ir}}$$

The model implies that the partial derivative of the i^{th} observation's dependent variable y_i with respect to the j^{th} observation's r^{th} explanatory variable x_{jr} is written as

$$\frac{\partial y_i}{\partial x_{jr}} = \beta_r [(\mathbf{I_n} - \lambda \mathbf{W})^{-1}]_{ij} \tag{A.9}$$

where β_r is the r^{th} element of the parameter vector $\boldsymbol{\beta}$ and $[(\mathbf{I_n} - \lambda \mathbf{W})^{-1}]_{ij}$ denotes the entry in the i^{th} row and j^{th} column of the matrix $(\mathbf{I_n} - \lambda \mathbf{W})^{-1}$. Using (A.9), ADE_r is computed as

$$ADE_r = \frac{1}{n}\sum_{i=1}^{n}\frac{\partial y_i}{\partial x_{ir}} = \beta_r \frac{1}{n} tr[(\mathbf{I_n} - \lambda\mathbf{W})^{-1}]$$

where $tr(\cdot)$ is the trace operator. Next, ATE is the average of total effects on the dependent variable of an observation unit caused by a change in an explanatory variable across all n units including own unit, or equivalently the average of total effects on the dependent variable of all observation units caused by a change of an explanatory variable in an observation unit. Formally, the ATE for the r^{th} explanatory variable is defined as

$$ATE_r = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n}\frac{\partial y_i}{\partial x_{jr}} = \frac{1}{n}\sum_{j=1}^{n}\sum_{i=1}^{n}\frac{\partial y_i}{\partial x_{jr}} = \beta_r \frac{1}{n}\boldsymbol{\iota}_n'(\mathbf{I_n} - \lambda\mathbf{W})^{-1}\boldsymbol{\iota}_n$$

Note that the ATE is the regression coefficient β_r multiplied by the factor $\boldsymbol{\iota}_n'(\mathbf{I_n} - \lambda\mathbf{W})^{-1}\boldsymbol{\iota}_n/n$, which we call the average total effect factor (ATEF). ATEF is the sum of all the entries of the matrix $(\mathbf{I_n} - \lambda\mathbf{W})^{-1}/n$ and thus should always greater than ADEF, which is the sum of the diagonal entries. In fact, the difference represents the neighborhood effects. So ANE is defined as the difference, i.e. total effects net of own effects. Formally, the ANE for the r^{th} explanatory variable is defined as

$$ANE_r = ATE_r - ANE_r = \beta_r \frac{1}{n}\{\boldsymbol{\iota}_n'(\mathbf{I_n} - \lambda\mathbf{W})^{-1}\boldsymbol{\iota}_n - tr[(\mathbf{I_n} - \lambda\mathbf{W})^{-1}]\}$$

Note that the ANE is the regression coefficient β_r multiplied by the factor $\{\boldsymbol{\iota}_n'(\mathbf{I_n} - \lambda\mathbf{W})^{-1}\boldsymbol{\iota}_n - tr[(\mathbf{I_n} - \lambda\mathbf{W})^{-1}]\}/n$, which we call the average total effect factor (ANEF). Obviously, ANEF is the difference between ATEF and ADEF.

As a variant of ANE, we introduce the average first order neighborhood effect (A1NE) to identify the effect only on the first order neighbors as defined by the weight matrix, not all the units, which is often more interesting than ANE. A1NE is the average of the weighted average effects on the dependent variable of the first order neighbors caused by a change in an explanatory variable in an observation unit. Formally, the A1NE for the r^{th} explanatory variable is defined as

$$A1NE_r = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij} \frac{\partial y_j}{\partial x_{ir}}$$

where w_{ij} is the entry in the i^{th} row and j^{th} column of the matrix $\mathbf{W}$. Note that the i^{th} row of $\mathbf{W}$ represents the weights of observation unit i's first neighbors and thus $\sum_{j=1}^{n} w_{ij}\ \partial y_j / \partial x_{ir}$ represents the weighted average of the first neighborhood effects. Using (A.9), $A1NE_r$ is computed as

$$A1NE_r = \frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}\,\beta_r [(\mathbf{I_n} - \lambda\mathbf{W})^{-1}]_{ji} = \beta_r \frac{1}{n} tr[\mathbf{W}(\mathbf{I_n} - \lambda\mathbf{W})^{-1}]$$

This is what we want to derive for (2.28).

Valuation of Agglomeration Factors using the Estimates

We apply this interpretation to the valuation of the effects of agglomeration factors. The existence of spatial lags leads to indirect/neighborhood effects as well as direct/own effects of a regional attribute for both worker-consumers and firms.

First, consider the valuation of an agglomeration factor by worker-consumers. (2.15) suggests that the valuation of a regional takes the ratio of the partial derivative of log(*pop*) with respect to an agglomeration factor to that with respect to income. An own valuation should take the ratio of the direct effect of the agglomeration factor to that of income. Formally, the own value of an agglomeration factor s_r is computed as

$$p_r^* = \frac{ADE_r(\lambda_1)}{ADE_{inc}(\lambda_1)} inc = \frac{ADEF(\lambda_1)\mu_{1r}}{ADEF(\lambda_1)\delta_{11}} inc = \frac{\mu_{1r}}{\delta_{11}} inc$$

where ADE's and ADEF's are computed as in (2.27) and expressed as a function of λ_1; and μ_{1r} is the r^{th} element of the parameter vector $\boldsymbol{\mu}_1$. Since the ADEF cancels out, the result is the same as when there is no spatial lag. Note that s_r is omitted in the denominator unlike in (2.15) because of the level form of specification of the agglomeration factor. When the logarithm form is used, it should appear in the denominator. A neighbor's valuation should take the ratio of the neighborhood effect of the agglomeration factor to the direct effect of income. Formally, the neighbor value of an agglomeration factor s_r is computed as

$$\bar{p}_r^* = \frac{A1NE_r(\lambda_1)}{ADE_{inc}(\lambda_1)} inc = \frac{A1NEF(\lambda_1)\mu_{1r}}{ADEF(\lambda_1)\delta_{11}} inc = A1NDR(\lambda_1)\frac{\mu_{1r}}{\delta_{11}} inc = A1NDR(\lambda_1)\, p_r^*$$

where A1NE and A1NEF, and A1NDR are defined as in (2.28) and (2.29), respectively. This result tells us that the average neighbor value is the own value multiplied by A1NDR. Since A1NDR does not depend on the regression parameters other than λ_1, the relative strength of the neighbor value to the own value is a constant, i.e. regardless of agglomeration factors. This is due to the model specification that the only spatial lag of the dependent variable summarizes the overall neighborhood effect. So A1NDR should be interpreted as the overall average neighborhood effect relative to the direct effect.

The own value of population size is imputed using (2.16) with the denominator being $ADE_{inc}(\lambda_1)$ since the value is translated into own income equivalent.

$$p_{pop}^* = -\frac{inc/pop}{ADE(\lambda_1)\delta_{11}}$$

The neighbor value of population size is imputed using (2.15) with the numerator being adjusted so that only a neighbor's population change is counted as follows:

$$\bar{p}_{pop}^* = \frac{\lambda_1 \cdot adj}{ADE(\lambda_1)\delta_{11}} \cdot \frac{inc}{pop}$$

where *adj* is the adjustment factor and it is defined as the average contribution of an observation unit's population increase to increase of the population of the neighborhood which it belongs to, i.e. $adj = \frac{1}{n}\sum_i 1/n(N_i)$, where N_i and $n(N_i)$ denote the set of observation unit i's neighbors and the number of its elements, respectively.

Next, consider the valuation of an agglomeration factor by firms. (2.19) − (2.22) give us the elasticities of cost with respect to an agglomeration factor and their translation into income values for the traded good and housing sectors. Even when there is the spatial lag for a dependent variable, the calculation using the equations does not change as is the case with the valuation of utility by worker-consumers. The only difference is that the partial derivative of a dependent variable with respect to an agglomeration factor is not the regression coefficient on the factor, but that multiplied by an appropriate factor. The multiplier should be $ADEF(\lambda_2)$ and $ADEF(\lambda_3)$ for the traded good and housing sectors, respectively for the own effect of an agglomeration factor, while it should be $A1NEF(\lambda_2)$ and $A1NEF(\lambda_3)$ for the neighborhood effect. The cost elasticities with respect to an agglomeration factor s_r for the two sectors are computed as

$$e_{C,r} = -ADEF(\lambda_2)\frac{\mu_{2r}}{\phi}s_r, \qquad \bar{e}_{C,r} = -A1NEF(\lambda_2)\frac{\mu_{2r}}{\phi}s_r$$

$$e_{G,r} = ADEF(\lambda_3)\mu_{3r}s_r, \qquad \bar{e}_{G,r} = A1NEF(\lambda_3)\mu_{3r}s_r$$

where $e_{C,r}$ and $e_{G,r}$ are the own cost elasticities for the traded good and housing sectors, respectively, while $\bar{e}_{C,r}$ and $\bar{e}_{G,r}$ are the neighbor cost elasticities; and μ_{2r} and μ_{3r} is the r^{th} element of the parameter vectors $\boldsymbol{\mu}_1$ and $\boldsymbol{\mu}_2$. Note that s_r is multiplied because the variable is used in the level form, while it is omitted when it is in the logarithmic form. The cost effect of an agglomeration factor s_r is translated into income value using (2.21) and (2.22) in the same way as above. In the case of the housing sector, the denominator in (2.22) should always be $ADE_{inc}(\lambda_3)$ because the cost effect should be translated to own income value even in the case of neighborhood effects. The results are as follows:

$$p_r^C = \frac{ADEF(\lambda_2)\mu_{2r} inc}{\phi}, \qquad \bar{p}_r^C = \frac{A1NEF(\lambda_2)\mu_{2r} inc}{\phi}$$

$$p_r^G = -\frac{\mu_{3r}}{\delta_{31}} inc, \qquad \bar{p}_r^G = -A1NDR(\lambda_3)\frac{\mu_{3r}}{\delta_{31}} inc$$

where p_r^C and p_r^G are the own values of cost savings due to an agglomeration factor s_r for the traded good and housing sectors, respectively, while $\bar{p}_r^C$ and $\bar{p}_r^G$ are the neighbor values. Note that s_r should be multiplied when the variable is used in the logarithmic form.

Appendix C: 3SLS Estimation Results for the Non-spatial Error Model

LHS variable	RHS variable	Estimate	Std Err	t Value	Pr > |t|
log(*pop*)	log(pop)lag	0.41172	0.087867	4.69	0.000
	log(inc)	3.128137	0.455314	6.87	0.000
	log(hpric)	-1.17918	0.342725	-3.44	0.001
	prptxshr	-27.8334	11.0038	-2.53	0.012
	restxr	0.086673	0.010281	8.43	0.000
	log(szret)	0.744343	0.329058	2.26	0.025
	log(pctrf)	-0.89243	0.198779	-4.49	0.000
	greatlakes	0.480562	0.16147	2.98	0.003
	log(area)	1.311708	0.221914	5.91	0.000
	snow	-0.00798	0.003813	-2.09	0.037
	tempjan	0.064873	0.020971	3.09	0.002
	constant	-29.6443	3.78374	-7.83	0.000
	R-squared	.8622	Adjusted R-Squared		.8423
	ADEF	1.0392	A1NEF		0.0994
log(*inc*)	log(inc)lag	0.151348	0.081877	1.85	0.066
	log(pop)	0.018752	0.009739	1.93	0.055
	indtxr	-0.00338	0.001079	-3.13	0.002
	log(pcexp)	0.077418	0.040649	1.9	0.058
	educ	1.521039	0.127781	11.9	0.000
	12gps	0.00554	0.001687	3.28	0.001
	lqman	0.039801	0.011828	3.36	0.001
	log(distair)	-0.00058	0.000368	-1.57	0.118
	age	0.094786	0.030439	3.11	0.002
	agesq	-0.00107	0.000436	-2.46	0.015
	unemp	-0.01886	0.009587	-1.97	0.050
	constant	5.795973	0.808805	7.17	0.000
	R-squared	.9145	Adjusted R-Squared		.9021
	ADEF	1.0063	A1NEF		0.0311
log(*hpric*)	log(hpric)lag	0.232181	0.074707	3.11	0.002
	log(pop)	0.135878	0.027015	5.03	0.000
	log(inc)	0.487697	0.09673	5.04	0.000
	indtxr	0.001879	0.001541	1.22	0.224
	log(rdnt)	-0.28079	0.063373	-4.43	0.000
	water	-0.20903	0.057457	-3.64	0.000

LHS variable	RHS variable	Estimate	Std Err	t Value	Pr > |t|
	hyear	-0.01137	0.001099	-10.35	0.000
	hroom	0.194383	0.036784	5.28	0.000
	log(area)	-0.11024	0.051702	-2.13	0.034
	constant	2.691129	1.072732	2.51	0.013
	R-squared	.9145	Adjusted R-Squared		.9046
	ADEF	1.0102	A1NEF		0.0497

Appendix D: Land Uses Matched to Industrial Codes

Land Use Code	Description	SIC 87	NAIC 97[*]
3000	Industrial vacant land	20--	31----
3007	Industrial vacant land	20--	31----
3010	Loose material and storage yard	4226	49319/
3020	Equipment and machinery storage yard	7359	5324//
3030	Salvage yard, scrap metals, etc.	5093	42193/
3040	Vehicle recycling yard	5093	42193/
3050	Billboard sites	7312	54185/
3070	Recreational vehicle storage yard	7519	53212/
3100	Food and drink processing plants and storage	2000	311///, 3121//
3110	Food and drink processing plants and storage	2000	311///, 3121//
3200	Foundries and heavy manufacturing plants	2800-3000, 3300-3800	324///-327///, 331///-336///, 339///
3300	Manufacturing and assembly, medium	2400-2600	321///, 322///, 337///
3301	Manufacturing and assembly, medium	2400-2600	321///, 322///, 337///
3306	Manufacturing and assembly, medium	2400-2600	321///, 322///, 337///
3330	Manufacturing and assembly, medium	2400-2600	321///, 322///, 337///
3331	Manufacturing and assembly, medium	2400-2600	321///, 322///, 337///
3332	Manufacturing and assembly, medium	2400-2600	321///, 322///, 337///
3349	Manufacturing and assembly, medium	2400-2600	321///, 322///, 337///
3400	Manufacturing and assembly, light	2300, 2700	315///, 323///
3430	Manufacturing and assembly, light	2300, 2700	315///, 323///
3499	Manufacturing and assembly, light	2300, 2700	315///, 323///
3500	Manufacturing -- type unknown	20--	31----
3510	Manufacturing -- type unknown	20--	31----
3550	Manufacturing -- type unknown	20--	31----
3590	Manufacturing -- type unknown	20--	31----
3600	Manufacturing -- type unknown	20--	31----
3650	Manufacturing -- type unknown	20--	31----
3700	Small shops (machine, tool and die, etc.)	3599	33271/
3710	Small shops (machine, tool and die, etc.)	3599	33271/

Land Use Code	Description	SIC 87	NAIC 97*
3770	Small shops (machine, tool and die, etc.)	3599	33271/
3780	Small shops (machine, tool and die, etc.)	3599	33271/
3900	Grain elevators	4221	49313/
3930	Contract and construction service facilities	15--	23----
3940	Bulk oil storage facilities	5171	42271/
3950	Research and development facilities	8730	5417//
3990	Other industrial structures	20--	31----
3995	INDUSTRIAL COMMON AREA	20--	31----
3999	Other industrial structures	20--	31----
4000	Commercial vacant land	50--, 60--, 70--	42----,44----,51---- - 56----, 61----, 62----, 71----, 72----, 81----
4004	Commercial vacant land	50--, 60--, 70--	42----,44----,51---- - 56----, 61----, 62----, 71----, 72----, 81----
4007	Commercial vacant land	50--, 60--, 70--	42----,44----,51---- - 56----, 61----, 62----, 71----, 72----, 81----
4092	Convalescent home	8050	623///
4095	Day care centers	8350	6244//
4100	Motels	7010	72111/
4110	Hotels	7010	72111/
4120	Nursing home	8050	623///
4121	Nursing home	8050	623///
4130	Hospital for profit	8060	622///
4150	Trailer or mobile home park	7030	7212//
4160	Commercial campgrounds	7030	7212//
4200	Small (under 7500 sq. ft.) detached retail	52--	44----
4210	Supermarkets	5410	44511/
4220	Discount stores and junior department stores	5310	4521//
4230	Furniture marts	5700	442///
4240	Full line department store	5310	4521//
4250	Strip center retail (4 or more, > 7500 sq. ft.)	5300	452///
4255	GENERAL RETAIL OVER 7500 SQ. FT.	5300	452///
4260	Community shopping center	5300	452///
4270	Regional shopping center	5300	452///
4275	Regional shopping center	5300	452///
4280	Franchise food stores	5400	445///
4285	Franchise food stores	5400	445///
4290	Other retail structures	52--	44----

Land Use Code	Description	SIC 87	NAIC 97*
4295	Retail Condominium	52--	44----
4300	Restaurant, cafeteria	5812	722212
4301	Nightclub restaurant	5813	7224//
4302	Party center	5800	722///
4310	Neighborhood tavern	5812	7221//
4320	Franchise food with sit down service	5812	7221//
4330	Franchise food with counter service only	5812	722211
4333	Franchise food with counter service only	5812	7221//
4340	Commercial -- unknown type	5812	7221//
4350	Drive in Restaurant	5812	7221//
4360	Ice cream stand (generally seasonal)	5812	722213
4370	Commercial -- unknown type	5800	722///
4390	Other food service structures	5800	722///
4400	Dry cleaning plants and laundries	7210	8123//
4410	Funeral homes	7260	8122//
4420	Medical clinics and offices	8010-8040, 8070-8090	621///
4421	Medical clinics and offices	8010-8040, 8070-8090	621///
4425	Medical clinics and offices (condos)	8010-8040, 8070-8090	621///
4429	Commercial -- unknown type	8000	62----
4430	Animal clinic or hospital	0740	54194/
4440	Full service bank	6020	52211/
4450	Savings and loan	6030	52212/
4458	Commercial -- unknown type	6000	52----
4470	Office buildings 1 and 2 stories	60--, 7300, 7800, 7900, 8100, 8300, 8700, 8900	51---- - 56----, 71----, 813///
4480	Office buildings 3 or more stories (walk up)	60--, 7300, 7800, 7900, 8100, 8300, 8700, 8900	51---- - 56----, 71----, 813///
4490	Office buildings 3 or more stories (elevator)	60--, 7300, 7800, 7900, 8100, 8300, 8700, 8900	51---- - 56----, 71----, 813///
4499	Commercial -- unknown type	60--, 7300, 7800, 7900, 8100, 8300, 8700, 8900	51---- - 56----, 71----, 813///
4500	Office condominium	60--, 7300, 7800, 7900, 8100, 8300, 8700, 8900	51---- - 56----, 71----, 813///
4510	Service station with kiosk (retail)	5540	44719/

Land Use Code	Description	SIC 87	NAIC 97*
4520	Full service gas station	5540	44711/
4523	Commercial -- unknown type	5540	447///
4530	Car wash	7542	811192
4540	Automobile car sales and service	5510	4411//
4545	Truck sales and service	5510	4411//
4548	Commercial -- unknown type	5500	441///
4550	Commercial parking garage	7520	81293/
4560	Commercial parking lot	7520	81293/
4565	Commercial parking lot assoc. with other use	7520	81293/
4568	Commercial -- unknown type	7500	811///
4570	Self serve car wash	7542	811192
4579	Commercial -- unknown type	7500	811///
458	Used car sales (lot with trailer)	5520	44112/
4580	Used car sales (lot with trailer)	5520	44112/
4584	Commercial -- unknown type	5500	441///
4585	Auto repair garage	7530	8111//
4589	Commercial -- unknown type	7530	8111//
4590	Franchise auto service center	7530	8111//
4600	Theaters	7830	512131
4610	Drive in theaters	7833	512132
4640	Bowling alleys	7930	71395/
4660	Amusement parks	7996	71311/
4680	Cultural and nature exhibition facility	8410	71211/
4690	Racketball and tennis clubs	7997	71394/
4700	Detached health spa	7990	7139//
4710	Home improvement center	5200	44411/
4720	Home garden center	5260	44422/
4770	Commercial -- unknown type	5200	444///
4780	Lumberyard and building materials	5210	4441//
4790	Mini storage warehouse	4225	49311/
4800	Commercial warehouse (under 75,000 sq. ft.)	4225	49311/
4805	Commercial warehouse (over 75,000 sq. ft.)	4225	49311/
4810	Commercial warehouse (loft type)	4225	49311/
4815	Regional distribution warehouse	4225	49311/
4816	Commercial -- unknown type	4200	493///
4818	Multi tenant warehouse (2+ units)	4225	49311/
4819	Warehouse condominium	4225	49311/
4820	Commercial truck terminal	4230	48849/

Land Use Code	Description	SIC 87	NAIC 97*
4850	Commercial -- unknown type	4200	493///
4865	Commercial -- unknown type	4200	493///
4868	Commercial -- unknown type	4200	493///
4870	Commercial -- unknown type	4200	493///
4880	Commercial -- unknown type	4200	493///
4885	Commercial -- unknown type	4200	493///
4890	Commercial -- unknown type	4200	493///
4900	Marine service facility	4400	483///
4910	Aircraft sales and service	4500	481///
4915	Commercial -- unknown type	4500	481///
4918	Commercial -- unknown type	4500	481///
4920	Commercial -- unknown type	4500	481///
4950	Commercial -- unknown type	4500	481///
4960	Marina (small boat)	4493	71393/
497	General retail with walk up apartments	5300	452///
4970	General retail with walk up apartments	5300	452///
4979	Commercial -- unknown type	5300	452///
498	General retail with walk up offices	5300	452///
4980	General retail with walk up offices	5300	452///
4990	Other commercial structures	50--, 60--, 70--	42----,44----,51---- - 56----, 61----, 62----, 71----, 72----, 81----
4995	Commercial Condominium	50--, 60--, 70--	42----,44----,51---- - 56----, 61----, 62----, 71----, 72----, 81----
4999	Other commercial structures	50--, 60--, 70--	42----,44----,51---- - 56----, 61----, 62----, 71----, 72----, 81----

* NAICS 2002 codes are same as NAICS 97 for the listed codes except the followings: 42193/ is changed to 42393/, and 42271/ to 42471/.

Appendix E: Definitions of Variables and Data Sources for Chapter 6

Variables	Units	Definitions	Data Sources
pop90	persons	Total population in 1990	Population Hosing Census 1990
popgrwth	percent	Gross population growth rate over the 10 year period 1990-2000	Population Hosing Census 1990, 2000; SOCDS*
popgw		*popgrwth* if *jobgrwth* is greater than zero, and zero otherwise	
popdcl		*popgrwth* if *jobgrwth* is smaller than zero, and zero otherwise	
jobgrwth	percent	Gross job growth rate over the 10 year period 1990-2000	Population Hosing Census 1990, 2000; SOCDS
jobgw		*jobgrwth* if greater than zero, and zero otherwise	
jobdcl		*jobgrwth* if smaller than zero, and zero otherwise	
*pop*2*job*90		Population to job ratio for 1990	Population Hosing Census 1990, 2000; SOCDS
*p*2*j*90*gw*		*pop*2*job*90 if *jobgrwth* is greater than zero, and zero otherwise	
*p*2*j*90*dcl*		*pop*2*job*90 if *jobgrwth* is smaller than zero, and zero otherwise	
*pop*2*job*00		Population to job ratio for 2000	Population Hosing Census 1990, 2000; SOCDS
*p*2*j*00*gw*		*pop*2*job*00 if *jobgrwth* is greater than zero, and zero otherwise	
*p*2*j*00*dcl*		*pop*2*job*00 if *jobgrwth* is smaller than zero, and zero otherwise	

*emp*2*job*90		Employment to job ratio for 1990	Population Hosing Census 1990, 2000; SOCDS*
*e*2*j*90*gw*		*emp*2*job*90 if *jobgrwth* is greater than zero, and zero otherwise	
*e*2*j*90*dcl*		*emp*2*job*90 if *jobgrwth* is smaller than zero, and zero otherwise	
*emp*2*job*00		Employment to job ratio for 2000	Population Hosing Census 1990, 2000; SOCDS
*e*2*j*00*gw*		*emp*2*job*00 if *jobgrwth* is greater than zero, and zero otherwise	
*e*2*j*00*dcl*		*emp*2*job*00 if *jobgrwth* is smaller than zero, and zero otherwise	
indvac91	percent	Vacancy rates in 1991 for industrial properties	SIOR** 1992
indabs91	percent	Net absorption to vacancy ratiofor industrial properties between 1990 and 1991	SIOR 1992
offvac91	percent	Vacancy rates in 1991 for all types of offices	SIOR 1992
cbdoffabs91	percent	Net absorption to vacancy ratio for CBD offices between 1990 and 1991	SIOR 1992
outoffabs91	percent	Net absorption to vacancy ratio for offices outside CBD between 1990 and 1991	SIOR 1992
mfgshr90	percent	Number of employees in Manufacturing sector divided by total employment in 1990	Population Hosing Census 1990

* SOCDS denotes *State of the Cities Data Systems* provided by U.S. Department of Housing and Urban Development (HUD).

**SIOR denotes *Comparative Statistics of Industrial and Office Real Estate Markets* produced by Society of Industrial and Office Realtors (SIOR).

Appendix F: Descriptive Statistics for the Empirical Model Variables

Variables for Chapter 2

Variable	N	Mean	Std Dev	Minimum	Maximum
pop	88	129134.19	216494.24	12813	1392131
inc	88	24602.45	4394.01	15674	41937
hpric	88	94323.86	23952.9	58400	190400
prtxshr	88	0.0263809	0.0052107	0.0155774	0.0459725
restxr	88	42.936678	5.7195244	31.488535	62.063444
indtxr	88	48.090695	7.6539106	31.811146	70.162165
pcexp	88	2.678611	0.449609	1.6708326	4.237599
rdnt	88	3.4662494	1.605449	2.0054787	11.395232
water	88	0.7715385	0.1800241	0.215859	1
educ	88	0.2073001	0.0722792	0.1035402	0.4729598
12*gps*	88	66.60594	5.8965554	51.38	79.18
szret	88	24.519293	4.9883393	13.070175	40.06587
pctrf	88	0.0295152	0.0074711	0.0186628	0.0534087
lqman	88	1.2188237	0.5536494	0	2.7215644
age	88	36.618182	2.3146979	25.7	41.6
unemp	88	4.4772727	1.1687234	2.7	7.3
hyear	88	35.75	7.0617148	11	49
hroom	88	5.7863636	0.3074485	5.2	6.9
area	88	465.32273	89.272004	228.21	702.44
snow	88	23.828125	13.793547	0.8	97
jantemp	88	26.018182	2.1300556	22	31.3
greatlakes	88	0.0795455	0.2721389	0	1
distair	88	47.704182	20.887995	6.9944496	98.66232
crime	88	2668.91	1699.02	111	7658
lqcns	88	1.0858083	0.3146105	0	2.0170775
lqret	88	1.1506441	0.19007	0.7712568	1.7062059
vacn	88	0.0821383	0.0462289	0.0358177	0.3547705
nofreeze	88	236.77273	10.888565	212.4	263.7

Variables for Chapter 4

Variable	N	Mean	Std Dev	Minimum	Maximum
tdd	34165	5.812264	13.693912	0	174
abnd	34165	0.110903	0.3140165	0	1
trend	34165	11.615759	3.1008592	6.2757857	15.618778
logsfval	30362	1.9320224	1.0339271	0	8.1618101
bldg	33928	0.587332	0.4923213	0	1
bldgcond	32767	3.3643958	3.0422659	0	9
zpempgr	30026	-0.0236875	0.1758394	-1	0.956847
empgrw	34012	0.0273498	0.3362525	-0.9329609	6.265902
deltract	34164	8.1344195	19.842119	0	676.95556
convrt	34165	0.1398215	0.3468068	0	1
dis_cbd	30372	6.8243358	4.0487132	0.0006727	18.452211
dis_ihw	30372	0.8920388	0.7934728	0.0001391	4.1420238
indust	34164	0.1984252	0.3988199	0	1
txrate	34165	73.613721	11.296355	40.51	126.1644
sale	34165	0.0322845	0.1767573	0	1
acre	30372	1.5643556	6.5716793	0.0006428	656.69594
east	30372	0.5806335	0.4934635	0	1

Variables for Chapter 6

Variable	N	Mean	Std Dev	Minimum	Maximum
pop90	326	238560.1	545695.5	10747	7371282
popgrwth	326	0.101954	0.20966	-0.15388	2.418316
jobgrwth	326	0.084748	0.195063	-0.34166	1.912803
*pop*2*job*90	326	1.598536	0.405752	0.627847	3.00259
*pop*2*job*00	326	1.630743	0.440508	0.583558	3.191433
*emp*2*job*90	326	0.724366	0.176014	0.246584	1.233191
*emp*2*job*00	326	0.736058	0.181861	0.204117	1.362143
popgw	217	0.163645	0.228994	-0.0923	2.418316
jobgw	217	0.174462	0.174699	0.0002	1.912803
*p*2*j*90*gw*	217	1.617548	0.409194	0.669677	3.00259
*p*2*j*00*gw*	217	1.600454	0.430142	0.583558	3.191433
*e*2*j*90*gw*	217	0.748371	0.172605	0.246584	1.233191
*e*2*j*00*gw*	217	0.743598	0.178553	0.204117	1.362143
popdcl	109	-0.02086	0.067326	-0.15388	0.185881
jobdcl	109	-0.09386	0.071379	-0.34166	-0.00136
*p*2*j*90*dcl*	109	1.560686	0.397966	0.627847	2.799992
*p*2*j*00*dcl*	109	1.691044	0.456487	0.766569	3.170209
*e*2*j*90*dcl*	109	0.676576	0.17373	0.278272	1.139399
*e*2*j*00*dcl*	109	0.721047	0.18821	0.291515	1.315497
popgrwth[*]	36	0.062956	0.105615	-0.12996	0.223
*indvac*91	36	0.117417	0.063713	0.011	0.235
*indabs*91	36	0.125625	0.265403	-0.375	0.909091
*offvac*91	36	0.178819	0.043995	0.097473	0.274746
*cbdoffabs*91	36	0.106911	0.15454	-0.12658	0.6
*outoffabs*91	36	0.169152	0.18982	-0.26853	0.652174
*mfgshr*90	36	0.132698	0.055145	0.042039	0.296034

**popgrwth* in this row represents the population growth variable only for the sample used for the model in Section 6.4.2

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