MACROECONOMIC PERFORMANCE AND EFFICIENCY OF MONETARY POLICY

DISSERTATION

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ABSTRACT

Since its inception, macroeconomics has been the study of the causes and consequences of business-cycle fluctuations. Delivering low, predictable inflation and high, steady output growth is the primary goal of every economic policymaker in the world.

As a result, we can assess the macroeconomic performance of any country by looking at the stability of prices and growth. By most accounts, these measures have shown improvement over the last few decades. A broad cross-section of both industrialized and developing countries shows more stable prices and more stable growth during the 1990s than during the 1980s.

The goal of my dissertation research is to develop a theoretical framework within which to study this observed general improvement in macroeconomic performance. In particular, my research concentrates on the role of monetary policy, asking whether improved policymaking by central bankers can account for the lower observed inflation and output growth fluctuations, or inflation and output variability.

To accomplish my objectives I develop a theoretical framework to explain how the monetary authority can successfully reduce the variability of inflation and output, which results in an *optimal policy rule*. As an empirical
application of the model, I look at different ways to measure improvements in the policymaking process. These measures quantify the changes in the efficiency with which monetary policymakers accomplish their jobs. Each measure has its advantages, and so I examine their relative merits. With the development and appraisal of these measures I expect to provide tools that central bankers could use to evaluate monetary policy implementation.

The conclusion from studying the changes in the macroeconomic performance for 24 countries is that a better, or more efficient, monetary policy has been the driving force behind improved macroeconomic performance for most of the analyzed countries.
Dedicated to my parents, Horst and Sandra, my sister Kim, my brother Julian, the members of the Panel, and the memory of Federico Luthmer (1973-1992)
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INTRODUCTION

Motivation

Over the past twenty years, macroeconomic performance has improved markedly in industrialized and developing countries alike. Both inflation and real growth are more stable now than they were in the 1980s. Looking at a sample of 24 countries we see that during 1990s, in 20 of them inflation variability fell and in 14 of them output volatility was lower than it had been during the previous decade.

There are a number of possible explanations for this widespread improvement in economic outcomes. There is the very real possibility that the world has become a more stable place, as a result of a lower exposure of the economies to shocks. Also, monetary policymakers may have become more skillful in carrying out their stabilization objectives. That is, monetary policy in the 1990s may have been more efficient than it was in the 1980s.

As a preliminary analysis to the issues of interest, we take a look at the data on macroeconomic outcomes for the 24 countries of our sample. We the provide a brief description of the methodology of research and the objectives we want to accomplish.
Empirical Facts

We study a sample of 24 countries, ranging from large industrial countries to small developing ones.\(^1\) Selection into our sample resulted primarily from data availability, with the absence of reliable data on short-term interest rates serving as the main restriction. Our first step is to take a simple look at the data on macroeconomic performance over the past 20 years. With this in mind, we analyze the behavior of inflation and output for two periods, 1983 to 1990 and 1991 to 1998. We choose 1983 as the starting year as a result of data availability for the interest rate, while the choice of 1998 as the final year of the sample is due to the fact that this is the last year before the European Monetary Union comes into effect, discontinuing independent interest rate policy in 11 of the countries.

To measure inflation and output volatility, we assume that policymakers are interested in achieving an inflation target of 2% and in minimizing the variability of output around its potential level.\(^2\) We discuss these assumptions at length in Chapters 2 and 3, where we consider alternative targets in our empirical analysis.

\(^1\)The list includes Australia, Austria, Belgium, Canada, Chile, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Portugal, Spain, Switzerland, Sweden, the United Kingdom, and the United States.

\(^2\)For each country, we measure potential output as Hodrick-Prescott filtered industrial production.
Figure I.1 presents the change in the variability of inflation and output for the 24 countries of interest. We can draw several conclusions from these data. First, in 11 countries, both output and inflation variability fell, implying an unambiguous improvement in performance. In an additional 9 countries, inflation variability fell, while output variability rose. In fact, for all members of the European Union, except Germany, inflation variability fell between the 1980s and the 1990s. This surely reflects the increasing importance placed by central banks on explicit or implicit inflation targeting in the 1990s. Finally, we note that seven out of the nine countries in which output variability rose

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3See Fry, Julius, Mahadeva, Roger and Sterne (2000) for a discussion of the changes in central bank targeting procedures.
were in the EU. This is consistent with the conclusions in Cecchetti and Ehrmann (2001) that the shift to inflation targeting can move countries along an output-inflation variability frontier, lowering the latter at the expense of the former. Importantly, though, none of the countries in our sample experienced an increase in both inflation and output variability.

The following section looks at the specific questions we want to address in this research, in order to explain both the observed improvements in performance and the differences across countries.
Objectives

The main objective of this dissertation research is to develop a theoretical framework and look at the empirical evidence to study the general increase in macroeconomic stability in the main economies of the world. Particularly, we focus our attention in two questions:

1. Should policymakers care about inflation and output variability and, if so, can they do something about it?

2. What accounts for the observed increase in macroeconomic stability?

Chapter 1 directly addresses how to answer the first question by setting up an equilibrium model, in which economic agents are uncertain about aggregate demand and aggregate supply shocks. The model's goal is to shed light into whether or not stabilizing inflation and output as near as possible to some given values is desirable for the economic agents. This feature helps us in developing a theoretical framework to explain how the monetary authority can successfully reduce the variability of inflation and output, with the use of an \textit{optimal policy rule}, which is the policy instrument response to the shocks that affect an economy.

If policymakers should indeed be concerned with the goal of stabilizing inflation and output as a means to achieving a better macroeconomic performance, and, most importantly, they have the necessary instruments and the
scope of action to perform that task, the observed increase in performance can result from a combination of two potential explanations: 1) a reduction in the variability of the aggregate supply shocks and 2) a more efficient policy by the monetary authority. Chapter 2 proposes a methodology for estimating aggregate supply and demand shocks and the relevant parameters of the economy, in order to be able to identify the relative contribution of each of these explanations. Chapter 3 considers an alternative methodology, which relies on the estimation and use of an efficiency frontier of inflation and output variability, which serves as an upper bound for the purpose of evaluating monetary policy performance.

Finally, Chapter 4 proposes a comparison across the measures of policy efficiency, both in terms of their methodologies of estimation and implications, as well as in terms of their usefulness and application to similar projects. This latter aspect is of key importance, since we are not only interested in accounting for the increased macroeconomic stability in the past years, but we also want to provide a robust framework and methodology, for its use to be considered by monetary authorities for evaluating policy efficiency (and the changes thereof) in the present and the future.
CHAPTER 1

THE ROLE OF MONETARY POLICY STABILIZATION UNDER ASYMMETRIC INFORMATION

1.1 Introduction

In this chapter we use an equilibrium model to derive the monetary policy maker's optimal response function, taking into account the interaction between individual firms and households and their participation in markets for goods and services. The theoretical formulation is used to set up a social optimization problem, where the main goal of society is to minimize inflation and output fluctuations.

The model has three basic features: First, a representative household and two price-setting firms characterize the behavior of all households and firms in the economy. Second, firms set their prices based on the private information they possess about the shocks that have affected the economy. If this information is not perfect, the presence of uncertainty can give rise to a more volatile economy in the absence of policy intervention. Finally, once we allow for monetary authority to set its policy instrument to control for prices and output fluctuations, the social optimization problem will result in an optimal
policy rule. This rule will be such that the effect of demand disturbances is completely neutralized, while the response of the rule to supply shocks will depend on the structure of the economy and the preferences regarding price versus output stabilization.

The objective of this chapter is twofold: First and foremost, we want to show why monetary authorities should play an active role in stabilizing inflation and output, as a means to reducing society's loss; and second, we want to explain how monetary policy can optimally perform this task. Section 1.2 describes the general setting in which maximizing economic agents need to make decisions under uncertainty as a result of unknown supply and demand shocks, followed by the analysis of a particular scenario where we assume a power technology and linear preferences. In Section 1.3 we draw some policy implications and present the theoretical framework in which the monetary authority can act in order to successfully reduce the variability of inflation and output around their respective steady-state values. The resulting control rule will make use of the knowledge of the structure of the economy, the nature of the information agents possess about the shocks, and society's preferences towards the goal of minimizing inflation and output variance. Section 1.4 presents some concluding remarks.
1.2 Equilibrium without Central Bank Intervention

1.2.1 General Setting

The objective of the model is to show how price stickiness may arise from a rational expectations optimization process in the presence of imperfect information, implying that monetary policy can have real effects on the economy. We begin by assuming that agents in the economy are initially uncertain about aggregate demand of goods and services - representing demand shocks - and about the state-of-the-art of technology in the economy - representing supply shocks. Agents, however, know the probability distribution of the expenditure shocks and the technology shocks.

The production side of the economy is summarized by the actions of two firms that produce an identical good \( Y \) and choose the price \( P_k \) \((k = 1, 2)\) in order to maximize expected profits. Profits are a function of a random production technology (which will depend on the size of the aggregate supply shocks), the output price, and the demand of an imported good \( x \). The price of this input \( (Q) \) is determined in the international markets, while the domestic price will be proportionately affected by the size of the demand shock \( (P_x = Qd) \).
Consumption of the $Y$ is undertaken by a representative household who receives her earnings from holding assets that yield a real return of $(W)$ per period, which is exogenously determined. The nominal returns demand directly on the size of the demand disturbance.

Before the demand shock $(d)$ and the technology shock $(s)$ are realized, each firm sets the price of the consumption good $P_k$, based on their estimates of the shocks. Once the state of nature $\vartheta = \{s, d\}$ is revealed, the representative household chooses the quantity of the good she wants to purchase. The household uses nominal returns income $(Wd)$ to purchase the consumption good at the given prices $P_1$ and $P_2$ and each firm has to undertake production and supply the amount of the good demanded at the price.

### 1.2.2 Two state case

Let us consider the case when the two firms are Betrand competitors. This implies that the consumer will purchase only from the firm that sets the lowest price or split consumption if the prices of the two firms are equal. Assuming that the consumer spends her entire nominal income, output will be given by:

\[
Y_1 = \frac{Wd}{P_1}, \quad Y_2 = 0; \text{ if } P_1 < P_2 \\
Y_1 = 0, \quad Y_2 = \frac{Wd}{P_2}; \text{ if } P_1 > P_2 \\
Y_1 = Y_2 = \frac{Wd}{2P}; \text{ if } P_1 = P_2 = P. \tag{1}
\]
Since neither firm has a fixed cost of production, profits for firm $k$ in domestic currency will be given by:

$$R_k = P_k Y_k - Q dx_k; \quad \text{if } P_k < P_{-k}$$

$$R_k = 0, \quad \text{if } P_k > P_{-k}$$

(2)

$$R_k = \frac{1}{2} [P_k Y_k - Q dx_k]; \quad \text{if } P_k = P_{-k}.$$  

Assuming that both firms have a production technology of the form $Y_k \equiv f_k[s, x_k] = sx_k^a$, it is straightforward to verify that profits for each firm will be given by:

$$R_k = d \left[ W - Q \left( \frac{Y}{s} \right)^{\frac{a}{a}} \right]; \quad \text{if } P_k < P_{-k}$$

$$R_k = 0, \quad \text{if } P_k > P_{-k}$$

(3)

$$R_k = \frac{d}{2} \left[ W - Q \left( \frac{Y}{s} \right)^{\frac{1}{a}} \right]; \quad \text{if } P_k = P_{-k}.$$  

As a helpful device to evaluate the different strategies, we assume that firms are interested in profits to the extent in which they can be used to purchase the goods in the international markets. Since the nominal price of $x$ is given by $Qd$, we define real profits as:

$$T_k = \frac{R_k}{d Q}.$$  

(4)

Let us consider the case in which the demand and supply shocks are independently drawn and each can take two values, high or low, i.e., $d^1 < d^2$ and $s^1 < d^2$. Hence, we have four possible states of nature: $u_{11} = \{d^1, s^1\}$;
\( v_{12} = \{d^1, s^2\}; \ v_{21} = \{d^2, s^1\}; \ v_{22} = \{d^2, s^2\}. \) To simplify the exposition, let us assume that \( d^1 = s^1 \) and \( d^2 = s^2. \) In this case, if shocks are perfectly observable, each firm will have three optimal choices for prices, that maximize profits; it is straightforward to verify that the price will be \textit{high} whenever the demand shock is high and the supply shock is low \( (P_h = P^*(v_{21})) \); the optimal price will be \textit{medium} if the firm experiences either both low shocks or high shocks \( (P_m = P^*(u_{11}) = P^*(u_{22})) \) and the firms will set a \textit{low} price whenever the demand shock is low and the supply shock is high \( (P_l = P^*(u_{12})). \) Given the nature of the demand function, any firm will capture the entire market and, hence, all the profits, if it sets the price below the one of its competitor; meanwhile, both firms will share the winnings if they set the same price. Hence, the decision making process for each firm can be represented in the following strategic form representation (since the game is symmetric, only real profits of firm 1 will be reported):
<table>
<thead>
<tr>
<th>$P_{2,h}$</th>
<th>$P_{1,h}$</th>
<th>$P_{1,m}$</th>
<th>$P_{1,l}$</th>
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<td>$\frac{1}{2} \left( \frac{W}{Q} - \left( \frac{Y_{m}^{1}}{s^{2}} \right)^{\frac{1}{\alpha}} \right)$</td>
<td>$\frac{W}{Q} - \left( \frac{Y_{m}^{1}}{s^{2}} \right)^{\frac{1}{\alpha}}$</td>
<td>$\frac{W}{Q} - \left( \frac{Y_{l}^{1}}{s^{2}} \right)^{\frac{1}{\alpha}}$</td>
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<tr>
<td>$P_{2,m}$</td>
<td>$0, 0, 0, 0$</td>
<td>$\frac{1}{2} \left( \frac{W}{Q} - \left( \frac{Y_{m}^{1}}{s^{2}} \right)^{\frac{1}{\alpha}} \right)$</td>
<td>$\frac{W}{Q} - \left( \frac{Y_{l}^{1}}{s^{2}} \right)^{\frac{1}{\alpha}}$</td>
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<tr>
<td>$P_{2,l}$</td>
<td>$0, 0, 0, 0$</td>
<td>$0, 0, 0, 0$</td>
<td>$\frac{1}{2} \left( \frac{W}{Q} - \left( \frac{Y_{l}^{1}}{s^{2}} \right)^{\frac{1}{\alpha}} \right)$</td>
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Since output is demand determined for a given price, $Y_{i}^{1}$ is given by equation (1), where the subscript $f$ represents the choice of the price between $P_{h}, P_{m}$ and $P_{l}$, and is defined as follows:

$$
Y_{h}^{1} = \frac{W d_{1}^{1}}{P_{h}}; \quad Y_{h}^{2} = \frac{W d_{2}^{2}}{P_{h}};
$$

$$
Y_{m}^{1} = \frac{W d_{1}^{1}}{P_{m}}; \quad Y_{m}^{2} = \frac{W d_{2}^{2}}{P_{m}};
$$

$$
Y_{l}^{1} = \frac{W d_{1}^{1}}{P_{l}}; \quad Y_{l}^{2} = \frac{W d_{2}^{2}}{P_{l}}.
$$

(5)

Let us focus now on the case in which neither shock is perfectly observed, but firms receive noisy signals about the states of nature: $\delta_{1i}$ and $\delta_{2i}$ for the demand disturbance and $\sigma_{1j}$ and $\sigma_{2j}$ for the supply shock. If we only allow firms to choose either of the three prices ($P_{h}$, $P_{m}$ and $P_{l}$) the expected payoffs for each firm $k$ are given by:
\[
\begin{align*}
\sum_{i=1}^{2} \sum_{j=1}^{2} \Pr(v_{ij}|\delta_k, \sigma_k) \frac{1}{2} \left[ \frac{W}{Q} - \left( \frac{Y_{ik}^i}{s_j} \right)^{\frac{1}{a}} \right] \Pr(P_k = P_{-k}) & \text{ if firm } k \text{ chooses } P_h; \\
\sum_{i=1}^{2} \sum_{j=1}^{2} \Pr(v_{ij}|\delta_k, \sigma_k) \frac{1}{2} \left[ \frac{W}{Q} - \left( \frac{Y_{ik}^i}{s_j} \right)^{\frac{1}{a}} \right] \Pr(P_k = P_{-k}) + \\
\sum_{i=1}^{2} \sum_{j=1}^{2} \Pr(v_{ij}|\delta_k, \sigma_k) \left[ \frac{W}{Q} - \left( \frac{Y_{ik}^i}{s_j} \right)^{\frac{1}{a}} \right] \Pr(P_k < P_{-k}) & \text{ if firm } k \text{ chooses } P_m; \\
\sum_{i=1}^{2} \sum_{j=1}^{2} \Pr(v_{ij}|\delta_k, \sigma_k) \frac{1}{2} \left[ \frac{W}{Q} - \left( \frac{Y_{ik}^i}{s_j} \right)^{\frac{1}{a}} \right] \Pr(P_k = P_{-k}) + \\
\sum_{i=1}^{2} \sum_{j=1}^{2} \Pr(v_{ij}|\delta_k, \sigma_k) \left[ \frac{W}{Q} - \left( \frac{Y_{ik}^i}{s_j} \right)^{\frac{1}{a}} \right] \Pr(P_k < P_{-k}) & \text{ if firm } k \text{ chooses } P_l.
\end{align*}
\]

(6)

In order to examine the implications of the presence of uncertainty in the price setting behavior, we turn our attention to a numerical example.
1.2.3 Numerical Example

Let us analyze the case of power technology and linear utility with a simple numerical example. Assume that $\alpha = \frac{1}{2}; W = 2; Q = 1; \Pr(v_{ij}) = \frac{1}{4}$, $\forall i, j \in \{1, 2\}; d^1 = s^1 = \frac{4}{5}$; and $d^2 = s^2 = \frac{5}{4}$. The optimal prices and quantities for each state of nature are given by:

\[
P_h \equiv P^*(v_{12}) = \frac{25}{8}; \quad Y_h^1 = \frac{64}{125}; \quad Y_h^2 = \frac{4}{5} \\
P_m \equiv P^*(v_{11}) = P^*(v_{22}) = 2; \quad Y_m^1 = \frac{4}{5}; \quad Y_m^2 = \frac{5}{4} \\
P_l \equiv P^*(v_{21}) = \frac{32}{25}; \quad Y_l^1 = \frac{5}{4}; \quad Y_l^2 = \frac{125}{64}
\]

(7)

First, we consider the perfect certainty case, i.e., when $\Pr(v_{ij} | \delta_k, \sigma_{jk}) = 1, \forall i, j \in \{1, 2\}$ and $\forall k \in \{1, 2\}$. The matrix of payoffs is given by:

<table>
<thead>
<tr>
<th></th>
<th>$P_{1,h}$</th>
<th>$P_{1,m}$</th>
<th>$P_{1,l}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{2,h}$</td>
<td>$\frac{497}{256}, \frac{497}{256}, 1-\frac{1}{2}$</td>
<td>$\frac{226}{512}, 1, 1 \frac{994}{625}$</td>
<td>$2 - \frac{525}{256}$, $\frac{525}{256}$, $\frac{525}{256}$</td>
</tr>
<tr>
<td>$P_{2,m}$</td>
<td>$0, 0, 0, 0$</td>
<td>$-\frac{113}{512}, \frac{113}{512}, \frac{113}{512}$</td>
<td>$-\frac{525}{256}$, $\frac{525}{256}$, $\frac{525}{256}$</td>
</tr>
<tr>
<td>$P_{2,l}$</td>
<td>$0, 0, 0, 0$</td>
<td>$0, 0, 0, 0$</td>
<td>$1-\frac{525}{256}$, $\frac{525}{256}$, $\frac{525}{256}$</td>
</tr>
</tbody>
</table>

Under perfect certainty, the optimal price - by definition - will be the one that maximizes joint profits for both firms, conditional on the state of nature. Moreover, for this particular numerical example, firms have no incentive to deviate from the symmetric price setting strategy, in order to steal profits from their competitor; nevertheless, this may not necessarily be always the
case in the presence of incomplete information, as we detail below. Hence, the Pure Strategies Nash Equilibrium (Nash, 1951) will be given by the following state-contingent prices, quantities and profits:

<table>
<thead>
<tr>
<th>State</th>
<th>Price</th>
<th>Output</th>
<th>Real Profits</th>
</tr>
</thead>
<tbody>
<tr>
<td>( v_{11} )</td>
<td>( P^*(v_{11}) = 2 )</td>
<td>( Y^*(v_{11}) = \frac{4}{5} )</td>
<td>( \frac{1}{2} )</td>
</tr>
<tr>
<td>( v_{12} )</td>
<td>( P^*(v_{12}) = \frac{25}{12} )</td>
<td>( Y^*(v_{12}) = \frac{1}{4} )</td>
<td>( \frac{1}{2} )</td>
</tr>
<tr>
<td>( v_{21} )</td>
<td>( P^*(v_{21}) = \frac{32}{25} )</td>
<td>( Y^*(v_{21}) = \frac{4}{5} )</td>
<td>( \frac{1}{2} )</td>
</tr>
<tr>
<td>( v_{22} )</td>
<td>( P^*(v_{22}) = 2 )</td>
<td>( Y^*(v_{22}) = \frac{5}{4} )</td>
<td>( \frac{1}{2} )</td>
</tr>
</tbody>
</table>

We now focus on the case of incomplete information. Specifically, we analyze the situation in which firms have complete uncertainty about the state of nature; i.e., \( \Pr(v_{ij}|\delta_{ik}, \sigma_{jk}) = \Pr(v_{ij}) = \frac{1}{4}, \forall i, j \in \{1, 2\} \) and \( \forall k \in \{1, 2\} \). This case does indeed give rise to the tension between setting a high price to increase profits and reducing it to steal market share. As a matter of fact, if the firms can only choose between \( P_h, P_m \) and \( P_l \) the best response will be to always set the price equal to \( P_m \), as can be shown with following payoff matrix:

| \( 2 \backslash 1 \) | \( P_{1.h} \) | \( P_{1.m} \) | \( P_{1.l} \) |
|-----------------|---------------|---------------|
| \( P_{2.h} \) | 0.7516 | 0.7872 | -0.9608 |
| \( P_{2.m} \) | 0 | 0.3936 | -0.9608 |
| \( P_{2.l} \) | 0 | 0 | -0.4804 |
Clearly, the dominant strategy is for each firm to choose $P_m$ and $(P_{1,m}, P_{2,m})$ is the only N.E. for this game. Hence, it follows that price stickiness (both upward and downward) can arise just from an optimization decision process under uncertainty (even assuming away wage stickiness and short-sightedness), which presents both an opportunity and a potential role for monetary policy to stabilize the economy, should the central bank have better information about the state of nature than private agents do. We discuss this more extensively in the next section.

Before we incorporate the role of monetary policy into the setting, it is useful to generalize the example to study the properties of the above described equilibria. The matrix of payoffs resulting from the model given in equation (1) can be represented as follows:

<table>
<thead>
<tr>
<th></th>
<th>$P_{1,h}$</th>
<th>$P_{1,m}$</th>
<th>$P_{1,l}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{2,h}$</td>
<td>$Y, \theta, \Theta, \psi$</td>
<td>$2 { \Phi, Y, Y, \Theta }$</td>
<td>$2 { \Omega, \Phi, \Phi, \gamma }$</td>
</tr>
<tr>
<td>$P_{2,m}$</td>
<td>$0, 0, 0, 0$</td>
<td>$\Phi, Y, Y, \Theta$</td>
<td>$2 { \Omega, \Phi, \Phi, \gamma }$</td>
</tr>
<tr>
<td>$P_{2,l}$</td>
<td>$0, 0, 0, 0$</td>
<td>$0, 0, 0, 0$</td>
<td>$\Omega, \Phi, \Phi, \gamma$</td>
</tr>
</tbody>
</table>

It is straightforward to show that $\Omega < \Phi < Y < \Theta < \psi$, when $s^1 \neq s^2$ and $d^1 \neq d^2$, and that all parameters in the payoff matrix converge to $Y = \frac{(1-\alpha)W}{2Q}$ as $s^1 \to s^2$ and $d^1 \to d^2$. This implies that for any possible values of the parameters $\alpha$, $W$ and $Q$ there are values of $s^1$, $s^2$, $d^1$ and $d^2$ such that $(P_{1,h},$
$P_{1,h}$ is a N.E.; others for which $(P_{1,m}, P_{1,m})$ is a N.E. and finally, other for which $(P_{1,i}, P_{1,i})$ is a N.E., in the presence of uncertainty.
1.3 The Role of Monetary Policy in Stabilization

1.3.1 Intervention in the Presence of Demand and Supply Shocks

In the previous section we showed that if firms have limited or no information about the state of the nature, prices will be sticky, which allows for real effects of monetary policy. We still need to argue why policy intervention would be desirable under these circumstances. One crucial assumption is needed for this result to hold, which is that the central bank must have better information than the firms about the nature and size of the shocks that affect the economy.

Let us first consider the case of a demand shock and assume without loss of generality that, in the absence of policy intervention, both firms will set their price to $P_k = P(\delta)$ as a result of the signal $\delta_k = \delta$ each of them receives. Normalizing $s$ to 1 equation (1) implies:

$$P(\delta) = \alpha^{-\alpha} \left( \frac{W}{2} \right)^{1-\alpha} Q^\alpha E(|d|),$$

(8)

$$Y_1 = Y_2 = \frac{Wd}{2P(\delta)}.$$ (9)

If firms "guess" the underlying demand shock correctly ($E(d|\delta) = d$), and hence, $P(\delta)$ coincides with the full information optimal price, output equals
the optimal one. However, if firms underestimate (overestimate) the size of the shock, \( P(\delta) \) results in a lower (higher) value than the full information price, which implies that output will be higher (lower) than the one prevailing under full information, which gives rise to output variability. Furthermore, the demand shock, even if it’s perfectly observed, will cause prices to move upward or downward, hence creating price variability.

Given the assumption that the central bank must have better information than the firms about the demand shock, if policymakers care about reducing both output and price fluctuations, this implies that policy intervention is always desirable in the presence of demand shocks. To show how this stabilization can take place, let us assume that the policy instrument has an inverse multiplicative effect on the demand shock. We represent this by rewriting equations (8) and (9) as:

\[
P(\delta) = \alpha^{-\alpha} \left( \frac{W}{2} \right)^{1-\alpha} Q^a E_r \frac{d}{r}[\delta, r],
\]

\[
Y_1 = Y_2 = \frac{W \frac{d}{r}}{2P(\delta)}.
\]

Under these circumstances, if the steady state value for \( d \) is \( d^* = 1 \), it will be in its best interest to completely neutralize the effect of the demand shock in order to completely eliminate price and output fluctuations by setting \( r = d \). Therefore, if policymakers care about reducing both output and price fluctuations, this implies that optimal policy intervention will always be such that the effect of demand shocks is completely neutralized.
We now turn to the case of the supply shock. To simplify the exposition, we assume that demand and supply shocks are independent \((E(d, s|\delta, \sigma) = E(d|\delta)E(s|\sigma))\), and allow the policy instrument to vary. If both firms observe \(\sigma_k = \sigma\) and set \(P_k = P(\sigma)\), the equilibrium conditions will be given by:

\[
P(\delta, \sigma) = \alpha^\alpha \left( \frac{W}{2} \right)^{1-\alpha} Q^\alpha E \left( \frac{d}{r|\delta} \right) [E(s|\sigma)]^{-1},
\]

(12)

\[
Y_1 = Y_2 = \frac{W \frac{d}{r}}{2P(\sigma)}.
\]

(13)

For a given demand shock, if the supply shock is perfectly observed \((E(s|\sigma) = s)\), prices and output will be equal to their optimal values, whereas if firms overestimate (underestimate) the magnitude of the disturbance, prices will be higher (lower) and output will be lower (higher) than the optimal ones. Therefore, as in the previous case, policy intervention could potentially play a stabilizing role.

Contrary to the demand shock, however, the supply shock moves prices and output in opposite directions, which implies that the monetary authority faces a trade-off in output fluctuations, vis-à-vis price fluctuations. Therefore, the optimal response of the central bank instrument to both demand and supply shocks will depend on the relative weights that society places on stabilization of output and prices. Before we turn to this aspect, however, it is useful to derive the dynamic behavior of prices and output, and we do so in the following section.
1.3.2 Behavior of Inflation and Output

Log-linearizing equations (12) and (13) and rearranging terms we obtain the following expressions:

\[ p \equiv \ln(P) = p^* + \ln E(d|\delta) - \ln E(r|\delta, \sigma) - \ln E(s|\sigma), \]  

(14)

\[ y \equiv \ln(Y_1 + Y_2) = y^* + \ln d - \ln E(d|\delta) - \ln r - \ln E(r|\delta, \sigma) \]  

+ \ln E(s|\sigma), \]  

(15)

where \( p^* = \alpha(\ln Q - \ln \alpha) + (1 - \alpha)(\ln W - \ln 2) \) is the steady state level of prices (i.e., the optimal level when \( r = d = s = 1 \)), and \( y^* = \ln 2 - \alpha(\ln Q - \ln \alpha) + \alpha(\ln W - \ln 2) \) is the level of output in the steady state. To express expectations as a function of the realized values of the variables, we assume firms apply a signal extraction process à la Lucas (1972) of the following nature:

\[ \ln E(d|\delta) = \beta_1 \ln d, \]  

(16)

\[ \ln E(s|\sigma) = \beta_2 \ln s, \]  

(17)

\[ \ln E(r|\delta, \sigma) = \beta_3 \ln r, \]  

(18)

where \( \beta_1, \beta_2, \beta_3 \in (0, 1) \). We can thusly rewrite (14) and (15) as:

\[ p = p^* + \beta_1 \ln d - \beta_3 \ln r - \beta_2 \ln s, \]  

(19)

\[ y = y^* + (1 - \beta_1) \ln d - (1 - \beta_3) \ln r + \beta_2 \ln s. \]  

(20)
Normalizing $d$ to $d'$ such that $\beta_1 = \beta_3$ we get:

$$p = p^* + \beta_1 (\ln d' - \ln r) - \beta_2 \ln s , \quad (21)$$

$$y = y^* + (1 - \beta_1)(\ln d' - \ln r) + \beta_2 \ln s . \quad (22)$$

Equations (21) and (22) arise as the result of assuming a power technology and linear preferences. For more general production and utility functions, the log-linear representation of prices and output will be given by:

$$p = p^* + \mu_{1p}(\ln d' - \ln r) - \mu_{2p} \ln s , \quad (23)$$

$$y = y^* + \mu_{1y}(\ln d' - \ln r) + \mu_{2y} \ln s , \quad (24)$$

where $\mu_{1p}$, $\mu_{2p}$, $\mu_{1y}$ and $\mu_{2y}$ are all positive, and are strictly positive if the central bank has an informational advantage over the agents about the shocks.

In order to introduce dynamics into the model, let us allow for both output and prices to change over time, i.e.:

$$p_t = p_t^* + \mu_{1p}(\ln d'_t - \ln r_t) - \mu_{2p} \ln s_t , \quad (25)$$

$$y_t = y_t^* + \mu_{1y}(\ln d'_t - \ln r_t) + \mu_{2y} \ln s_t . \quad (26)$$

Subtracting $p_{t-1}$ on both sides of (25) and letting $\pi_t = p_t - p_{t-1}$ and $\pi_t^* = p_t^* - p_{t-1}$ allows us to obtain the dynamics of inflation:

$$\pi_t = \pi_t^* + \mu_{1p}(\ln d'_t - \ln r_t) - \mu_{2p} \ln s_t . \quad (27)$$
From (26) and (27) we can derive and aggregate demand - aggregate supply representation of the economy. Aggregate demand (AD) is the negative relationship between \((y_t - y_t^*)\) and \((\pi_t - \pi_t^*)\) that is shifted by the demand shock and the policy instrument:

\[
y_t - y_t^* = -\omega (\pi_t - \pi_t^*) - \phi (\ln r_t - \ln d_t^r),
\]

where \(\omega = \frac{\mu_{2y}}{\mu_{2p}} > 0\) and \(\phi = \mu_{1y} + \frac{\mu_{12y} \mu_{2y}}{\mu_{2p}} > 0\). Analogously, aggregate supply (AS) is the positive relationship between \((\pi_t - \pi_t^*)\) and \((y_t - y_t^*)\) that is shifted by the supply shock, i.e.:

\[
\pi_t - \pi_t^* = \gamma (y_t - y_t^*) - \kappa \ln s_t ,
\]

where \(\gamma = \frac{\mu_{1p}}{\mu_{1y}}\) and \(\kappa = \frac{\mu_{1p} \mu_{12y} \mu_{2y}}{\mu_{1y}}\).

Finally, in order to simplify notation and future computations, we normalize \(s\) to \(s'\) so that \(\kappa = 1\) and redefine \(r_t = \ln r_t; d_t = \ln d_t^r;\) and \(s_t = \ln s_t'.\) Rewriting equations (28) and (29) gives rise to the following AD-AS model:

\[
y_t - y_t^* = -\omega (\pi_t - \pi_t^*) - \phi (r_t - d_t) ,
\]

\[
\pi_t - \pi_t^* = \gamma (y_t - y_t^*) - s_t .
\]

The policymaker will take into consideration a dynamic representation of the economy such as the one given by (30) and (31) in order to reduce inflation and output fluctuations, given society’s preferences. The derivation of the authority’s optimal policy rule is described in the next section.
1.3.3 Society’s Loss Function and Optimal Monetary Policy

As we discussed above, the optimal response of monetary policy to the underlying shocks should depend on the relative weight that society places on reducing fluctuations in prices (or inflation) vis-à-vis output (or output growth). We represent society’s preferences towards stabilizing inflation and output through a standard quadratic loss function used in most contemporary analyses of central bank policy, i.e.:

\[ L = E[\lambda (\pi_t - \pi^T)^2 + (1 - \lambda)(y_t - y^T)^2] ; \ 0 \leq \lambda \leq 1 , \]  \hspace{1cm} (32)

where \( E \) is the expectation operator; \( \pi^T \) and \( y^T \) are the target levels for inflation and output; and \( \lambda \) is the relative weight given to squared deviations of inflation and output from their desired levels.

We assume that the central bank’s objective is in line with society’s preferences, and that the target levels for both inflation and output are given by their steady state values \( (\pi^*_t = \pi^*_t \text{ and } y^*_t = y^*_t) \). Hence, the policy maker sets the instrument in order to minimize the loss function (32) subject to the structure of the economy given by (30) and (31), which yields the following expression for \( r_t \):

\[ r_t = a \sigma_t + b \varepsilon_t , \]  \hspace{1cm} (33)

Solving for the optimal policy rule \( r^* \) in terms of the aggregate demand and aggregate supply shocks yields equation (33), where \( a^* \) and \( b^* \) are given by:
\[ a^* = 1, \]
\[ b^* = \frac{-\lambda \gamma + (1 - \lambda) \omega}{\phi[\lambda \gamma^2 + (1 - \lambda)]}. \]

(34) \hspace{2.5cm} (35)

Consistent with our explanation at the beginning of the section, optimal policy will be such that the central bank should choose the value of the instrument to as to completely offset the effect of demand shocks (hence \( a^* = 1 \)). In the presence of supply shocks, policy makers face a trade-off between price and output stability. The reaction of the instrument to such shocks will depend on society’s preferences \((\lambda)\), and on the structure of the economy (which depends, among other factors, on the firms’ ability to observe the underlying shocks) represented by the parameters \(\gamma, \omega\) and \(\phi\).

Summarizing, as long as agents in the economy possess less information about the shocks that affect the economy than the monetary authority, it will always be in the agents best interest to allow central bank intervention. The more informed central banks are about the nature and size of the shocks, the closer they get to applying an optimal policy, hence reducing society’s loss from inflation and output fluctuations.
1.4 Conclusion

The model developed in this chapter presents a theoretical justification for the inflexibility of prices to move upward or downward, as a result of firms’ inability to perfectly observe demand and supply shocks. This price stickiness arises solely as a consequence of uncertainty, and it does not require either prices or wages to be predetermined. The two main implications of this result are that the monetary authority can have real effects on the economy and, more importantly, it provides a rationale for policy intervention in the case that the central bank has more information about the nature and size of the shocks than private agents.

As a direct consequences, we have been able to establish that the authority can successfully reduce inflation and output fluctuations by following an optimal policy rule. This rule is a function of the observed demand and supply disturbances, and the optimal reaction will always entail completely neutralizing demand shocks, and reacting to supply shocks in accordance with society’s preferences of inflation versus output stability, the structure of the economy and the agents’ information about the underlying shocks.
CHAPTER 2

MONETARY POLICY EFFICIENCY AND THE OPTIMAL POLICY RULE\textsuperscript{4}

2.1 Introduction

The theoretical arguments provided in Chapter 1 suggest that monetary policy can have real effects in the economy and, more importantly, policy intervention is desirable to achieve lower variability of inflation and output in the presence of aggregate shocks. Therefore, as we suggested in the introduction to this work, monetary policy can be indeed partly responsible for the observed changes in inflation and output growth variability, or macroeconomic performance. Nevertheless, as we also pointed out at the beginning, less volatile prices and production can also result from a lower exposure of the economy to aggregate disturbances. The next two chapters study two alternative empirical methods to be able to establish how important has been the contribution of better policy making, and to what extent have the im-

\textsuperscript{4}A substantial part of the research was undertaken while I was participating at the Graduate Research Programme at the European Central Bank during the Summer of 2001.
proved macroeconomic outcomes been the result of less variable supply and demand shocks.

The objective of this chapter is to develop a first approach to measuring the contribution of improved monetary policy to the observed changes in macroeconomic performance. Specifically, we look at the changes in the variability of inflation and output for the 24 industrialized and developing economies in our sample and compare the 1980s and the 1990s. We estimate a simple macroeconomic model of inflation and output for each country specifying the dynamics of inflation and output as a function of the interest rate — our measure of central bank policy — as well as additional exogenous variables. Using the estimated model, we are able identify the monetary policy rules as a function of the aggregate shocks and the parameters of the economy, for two sample periods, 1983 to 1990 and 1991 to 1998. This enables us to compute the change in macroeconomic performance for each country using a weighted sum of inflation and output volatility, and examine how much of that change can be accounted for by changes in the volatility of the aggregate shocks and how much can be ascribed to improvements in policy efficiency.

Throughout this chapter and the next we assume that improved macroeconomic policy is better monetary policy, and that the major tool for stabilization policy is the central bank's adjustment of the interest rate. In this

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5We explain the sample selection properties in the introduction to this dissertation.
view, improved efficiency means more skillful central bankers. Clearly there are factors beyond the proficiency of monetary policymakers per se that will lead to improved overall economic outcomes. Specifically, the environment has to be one in which the policymakers can actually do their jobs. If, as is sometimes the case, central bankers have little control over financial affairs, then the level of their expertise is irrelevant. As Cecchetti and Krause (2001) discuss, whether or not a central banker can actually stabilize the economy will depend on the financial structure in a country. Furthermore, changes in independence, credibility and transparency of policy can affect the ability of policymakers to perform effectively.6 Finally, there are a myriad of fiscal, trade and labor market policies that affect macroeconomic structure and so will have an impact both on location of the efficiency frontier and on monetary policy effectiveness.7 While our techniques are too coarse to distinguish among all of these possible causes of the changes that we document, we consider them a necessary first step.

At the end of Chapter 3, in Section 3.5, we look at some possible explanations for the cross country differences in macroeconomic performance and policy efficiency; in particular, we ask if the move to more independent

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7For instance, a lower level of inventories held by firms may reduce the effects of supply disturbances to the economy (Kahn, McConnell and Pérez-Quirós, 2000). In this paper we are only interested in the effect that the actual shocks have in the economy and therefore such technology improvements would be shown as a reduction in the variability of aggregate supply shocks.
and transparent central banks could be partly responsible for the observed changes.

The remainder of the chapter is divided into the following sections. In Section 2.2 we introduce the proposed methodology to analyze the changes in macroeconomic performance and determine the role of monetary policy in the stabilization of inflation and output. The main tool used to compare policy efficiency between the two periods of interest is to contrast the actual policy followed by central banks with an optimal policy rule, which results from an optimization program. The novelty of this approach consists of deriving and estimating the rules as policy responses to aggregate shocks, instead of macroeconomic variables.

Section 2.3 presents and discusses the main results. Our findings suggest that improved monetary policy has played an important stabilization role in almost all countries. At the same time, most countries also experienced reduced demand and supply shock variability, making in at least eight a substantial contribution towards improved performance. Section 2.4 concludes.
2.2 Methodology for Measuring Macro Performance and Policy Efficiency

As described in the previous section, we are interested in deriving a method to determine the sources of the observed increase in macroeconomic performance and changes in policy efficiency. For this purpose we assume that the monetary authority follows a linear policy rule which can be expressed as a function of the aggregate demand and aggregate supply shocks. First, we construct a theoretical framework to derive the optimal and actual policy rules as a function of the structural parameters of the economy and the aggregate disturbances; this information also allows us to identify the relative preferences towards minimizing inflation and output variability. We then introduce the measures of macroeconomic performance and monetary policy efficiency, and finally, we focus on the procedure for estimating the relevant parameters of the economy and the aggregate supply and demand shocks - for two different periods - in order estimate the suggested measures.

2.2.1 The Role of Policy in Stabilization

We assume that the primary concern of monetary policy is to achieve stabilization of the economy through the reduction in the variability of prices and output growth. In doing this we abstract from other policy goals, such as stabilizing exchange rates and interest rates, for we consider that these
serve rather as intermediate goals towards achieving domestic macroeconomic performance, measured by price and output stability. We summarize the central bank’s objective by invoking the quadratic loss function we presented at the end of Chapter 1, which we reproduce here for convenience:

\[ \mathcal{L} = E_t [\lambda (\pi_t - \pi_t^*)^2 + (1 - \lambda)(y_t - y_t^*)^2] ; \ 0 \leq \lambda \leq 1 \ , \quad (36) \]

where \( E_t \) is the expectation operator at time \( t \); \( \pi \) is inflation; \( y \) is (log) aggregate output; \( \pi^T \) and \( y^T \) are the target levels of inflation and output; and \( \lambda \) is the relative weight given to squared deviations of inflation and output from their desired levels.\(^8\)

Minimization of this loss requires knowledge of the determinants of deviations of inflation and output from their respective targets. Assuming that central banks consider the steady-state values of inflation and output as targets, we start with the stylized AD-AS model described by equations (30) and (31) in Chapter 1:

\[ y_t - y_t^* = -\omega (\pi_t - \pi_t^*) - \phi (r_t - d_t) \ , \quad (37) \]

\[ \pi_t - \pi_t^* = \gamma (y_t - y_t^*) - s_t \ . \quad (38) \]

where \( \omega \) is the inverse of the slope of the aggregate demand function, \(-\phi\) is the real interest rate semi-elasticity, and \( \gamma \) is the slope of the aggregate supply function.

\(^8\lambda \) can be also interpreted as the policy maker’s aversion to inflation variability (see Cecchetti and Ehrmann, 2001).
Combining (37) and (38) we obtain expressions for \((y - y^T)\) and \((\pi - \pi^T)\) as a function of the structural parameters, the aggregate shocks and the policy instrument:

\[
y - y^T = \frac{-\phi(r - d) + \omega s}{1 + \omega \gamma}, \tag{39}
\]

\[
\pi - \pi^T = \frac{-\phi \gamma (r - d) - s}{1 + \omega \gamma}. \tag{40}
\]

We know from our derivation in Section 1.3.3 that the resulting optimal policy rule will be given by:

\[
r = ad + bs, \tag{41}
\]

where the optimal values for the coefficients \(a\) and \(b\) are:

\[
a^* = 1, \tag{42}
\]

\[
b^* = \frac{-\lambda \gamma + (1 - \lambda) \omega}{\phi[\lambda \gamma^2 + (1 - \lambda)]}. \tag{43}
\]

The optimal policy rule gives us a benchmark criterion for evaluating policy efficiency; the closer the actual policy rule is to the optimal one in a given country, the higher the degree of policy efficiency. Hence, we are interested in deriving the coefficients \(a\) and \(b\) of the actual policy rule. The procedure is as follows: Starting from the reduced form representation of the economy, given by equations (39) and (40), we substitute the linear policy rule of equation (41). By construction, we can define the aggregate supply and demand shocks in such a way that they will be uncorrelated \((\sigma_{d,s} = 0)\).
Redefining \( y_t = y_t - y^T_t \) and \( \pi_t = \pi_t - \pi^T_t \) the observed variances of output and inflation around their target levels can be given by the following expressions:

\[
\begin{align*}
\text{Var}(y_t) & \equiv E(y_t - y^T_t)^2 = (1 + \omega\gamma)^{-2}(\phi^2(a - 1)^2\sigma_a^2 + (\omega - \phi b)^2\sigma_s^2) \quad (44) \\
\text{Var}(\pi_t) & \equiv E(\pi_t - \pi^T_t)^2 = (1 + \omega\gamma)^{-2}(\gamma^2\phi^2(a - 1)^2\sigma_d^2 + \\
& (1 + \gamma\phi b)^2\sigma_{\pi_1}^2).
\end{align*}
\]

Combining equations (44) and (45) we can solve for the parameter \( b \) of the actual policy rule:

\[
b = \frac{(1 + \omega\gamma)(\sigma_x^2 - \gamma^2\sigma_y^2) - (1 - \omega\gamma)\sigma_s^2}{2\gamma\phi\sigma_{\pi_1}^2}.
\] (46)

Given the estimate for \( b \) and equation (44) we obtain the squared deviation of \( a \) from its optimal value, i.e.:

\[
(a - 1)^2 = \frac{(1 + \omega\gamma)^2\sigma_y^2 - (\omega - \phi b)^2\sigma_s^2}{\phi^2\sigma_d^2}.
\] (47)

These derivations also allow us to obtain the variances of inflation and output under optimal policy (\( \text{Var}(\pi)^* \) and \( \text{Var}(y)^* \)) and the coefficient of aversion to inflation variability (\( \lambda \)). The optimal variances are derived assuming that policy completely offsets aggregate demand shocks \( (a = 1) \), i.e.:

\[
\begin{align*}
\text{Var}(y_t)^* & = (1 + \omega\gamma)^{-2}(\omega - \phi b)^2\sigma_s^2, \\
\text{Var}(\pi_t)^* & = (1 + \omega\gamma)^{-2}(1 + \gamma\phi b)^2\sigma_s^2.
\end{align*}
\] (48) (49)
while the coefficient of aversion to inflation variability can be derived by combining equations (43) and (46):

$$
\lambda = \frac{(\omega - \phi b)}{(\omega - \phi b) + \gamma(1 + \gamma \phi b)}.
$$

(50)

The policy maker’s preferences will depend on the reaction of policy to supply shocks; if the monetary authority only cares about reducing inflation variability ($\lambda = 1$), it will completely offset the effect of supply shocks on inflation (since it implies that $1 + \gamma \phi b = 0$), and conversely, for the case in which the only goal is output stability ($\lambda = 0$). The exercise of obtaining the preferences through the use of the knowledge of the structure of the economy and the policy rule is consistent with the discussion provided by Favero and Rovelli (1999); namely that, given a policy environment, it is possible to reverse engineer the preferences of the policy maker.9

The optimal variances and the coefficient of aversion to inflation variability will be used in the derivation of the measures of macroeconomic performance and policy efficiency. We turn to this issue next.

2.2.2 Proposed Measures for Performance and Efficiency Changes

In this subsection we define the theoretical measures of changes in performance and changes in policy efficiency that we shall use in our empirical

---

9See Cecchetti, McConnell and Pérez- Quiró (1999) and Cecchetti and Ehrmann (2001) for empirical applications to countries in the EU, and Dennis (2001) and Rudebusch (2001) for the case of the US.
computations. To compute macroeconomic performance, we make use of the loss function in equation (36) in order to construct a single measure of increased stability. The performance measure will then be the weighted sum of the observed variances of inflation and output, given for each period $i (=1,2)$ by:

$$P_i = \lambda \text{Var}(\pi_i) + (1 - \lambda)\text{Var}(y_i),$$  \hspace{1cm} (51)$$

where the weights $\lambda$ and $1 - \lambda$ are derived using equation (50). The change in macroeconomic performance is just the change in the measure from one period to the next, $\Delta P = P_1 - P_2$. If $\Delta P$ is positive we interpret this as a performance gain.

We evaluate monetary policy efficiency by looking at how close the actual performance is to the one under optimal policy. Consistent with this, policy inefficiency for each period is given by:

$$E_i = \lambda[\text{Var}(\pi_i) - \text{Var}(\pi_i)^*] + (1 - \lambda)[\text{Var}(y_i) - \text{Var}(y_i)^*],$$  \hspace{1cm} (52)$$

where the optimal variances $\text{Var}(y)^*$ and $\text{Var}(\pi_i)^*$ are given by (48) and (49), respectively. This measure of efficiency incorporates the comparison of the actual policy rule followed by the authorities, which results in the observed variances of inflation and output, and the optimal policy rule, which yields the optimal values for these variances. Since $E_i$ will be smaller the closer actual outcomes are to the optimal, i.e., the closer the actual policy rule is to the optimal one, our measure of the change in policy efficiency follows
immediately as the difference $\Delta E = E_1 - E_2$. We interpret positive values of $\Delta E$ as increases in the efficiency of monetary policy. When $\Delta E$ is negative, it suggests that policy making has deteriorated as the variances of inflation and output have moved further away from their optimal values.

Finally, we calculate the proportion that can be accounted for by improved policy using the following ratio:

$$Q = \frac{\Delta E}{|\Delta P|}.$$  \hspace{1cm} (53)

Given that the absolute value of the performance gain is in the denominator, a positive value of $Q$ implies improved policy efficiency, whereas a negative $Q$ implies that policy has become less efficient. If we observe a macro performance gain at the same time as policy has become more efficient and the variance of the aggregate shocks has become smaller, $Q$ will be between 0 and 1 and can be interpreted as the relative contribution of a more efficient policy towards the achievement of a macro performance gain.

Implementing the procedure we have just described requires us to follow several steps. First we must construct and estimate a dynamic model of inflation and output for both periods of interest. The dynamic model is used to identify the structural parameters, the aggregate supply and demand disturbances and their respective variances, which allow us to derive the monetary policy rule and the optimal variances. These, in turn, will enable us to compute $\Delta P$, $\Delta E$ and $Q$. 

38
2.2.3 Estimating the Structural Parameters and Aggregate Shocks

Let us consider again the stylized model in equations (41) and (42):

\[ y_t = -\omega \pi_t - \phi (r_t - d_t) \]  \hspace{1cm} (58)

\[ \pi_t = \gamma y_t - s_t \]  \hspace{1cm} (59)

As such, estimating the system only allows us to identify the parameter \( \gamma \). Hence, in order to achieve the identification of \( \omega \) and \( \phi \) we assume that the aggregate supply shock can be decomposed into a domestic and a foreign component, namely:

\[ s_t = h_t - \psi f_t \]  \hspace{1cm} (60)

where \( h \) represents the domestic (home) component of the shock, while \( f \) represents the foreign disturbance. The underlying assumption is that \( f \) affects domestic prices directly, while its impact on output arises indirectly through its effect on inflation. To be consistent with this description, we will use external price inflation as a proxy for \( f \) in the estimation, as we detail below.
The stylized model in equations (54) and (55) can be reformulated to take into account the dynamic behavior of the economy, a feature present in the data. To accomplish this, we assume that the demand disturbance and the domestic component of the supply disturbance have persistent effects on the economy and model $d_t$ and $h_t$ as AR(2) processes; i.e.:\textsuperscript{10}

$$
d_t = k_{d,t} + \varphi_1 d_{t-1} + \varphi_2 d_{t-2} ; E_t(k_{d,t}) = 0 , \quad (57)
$$

$$
h_t = k_{h,t} + \chi_1 h_{t-1} + \chi_2 h_{t-2} ; E_t(k_{h,t}) = 0 . \quad (58)
$$

Using equations (54), (55) and (56) we can represent the aggregate shocks as:

$$
d_t = \frac{y_t + \omega \pi_t}{\phi} + r_t , \quad (59)
$$

$$
h_t = s_t - \psi f_t = \gamma y_t - \pi_t - \psi f_t . \quad (60)
$$

We note that this method of identifying aggregate shocks clearly differs from the one used in the literature following the seminal works by Blanchard and Quah (1989) and King, Plosser, Stock and Watson (1991). The approach consists in exploiting cointegration relationships in the economy to extract the disturbances, by identifying permanent or persistent disturbances as "supply shocks" and temporary ones as "demand shocks". Our method directly identifies the shocks by considering their effects on the economic\textsuperscript{10}

\textsuperscript{10} The assumption about the autoregressive structure of the shocks is only crucial in terms of determining the order of the Vector Autoregression in equations (65) and (66). Specifically, for the current specification of the AD-AS model, an AR(n) process for the disturbances will result in the estimation of a n-order VAR.
variables, which is similar in nature to the approaches used by Uhlig (1999) and Canova and de Nicoló (2000).

Given the expressions (63) and (64) we can arrange the aggregate demand-aggregate supply model such that we are able to identify and estimate the structural parameters. Substituting (63) into the right-hand side of (61) and the solution into (58) yields:

$$y_t = -\omega \pi_t - \phi (r_t + \varphi_1 r_{t-1} + \varphi_2 r_{t-2}) + \varphi_1 y_{t-1} + \varphi_2 y_{t-2} + \omega \varphi_1 \pi_{t-1} \tag{65}$$

$$+ \omega \varphi_2 \pi_{t-2} + \phi k_{d,t} .$$

Analogously, substituting (64) into the right-hand side of (62) and the solution into (59) results in the following:

$$\pi_t = \gamma y_t + \psi (f_t + \chi_1 f_{t-1} + \chi_2 f_{t-2}) - \gamma \chi_1 y_{t-1} - \gamma \chi_2 y_{t-2} + \chi_1 \pi_{t-1} \tag{66}$$

$$+ \chi_2 \pi_{t-2} - k_{h,t} .$$

The system in equations (65) and (66) represents a dynamic aggregate demand-aggregate supply model. To make its estimation operational, we proxy the term $\widetilde{r}_t + \varphi_1 \widetilde{r}_{t-1} + \varphi_2 \widetilde{r}_{t-2}$ with the lagged demeaned ex-post real interest rate ($\widetilde{i}_{t-1} - \widetilde{\pi}_{t-1}$), where $i$ is the short-term nominal interest; while the proxy for the expression $f_t + \chi_1 f_{t-1} + \chi_2 f_{t-2}$ is one lag of demeaned external price inflation ($\widetilde{e}_{t-1} + \widetilde{\pi}_{t-1}$), where $e$ is exchange rate devaluation and $\pi^z$ is foreign inflation. Taking this into account, we estimate the dynamic behavior of output and inflation through the following:
\[ \begin{align*}
\bar{y}_t &= -\omega \bar{\pi}_t - \phi(\bar{y}_{t-1} - \bar{\pi}_{t-1}) + \sum_{l=1}^{2} \alpha_{1l}\bar{y}_{t-l} + \sum_{l=1}^{2} \alpha_{1(l+2)}\bar{\pi}_{t-l} \\
&\quad + \alpha_{15}Z_{t-1} + u_{yt}, \\
\bar{\pi}_t &= \gamma \bar{y}_t + \psi(\bar{c}_{t-1} + \bar{\pi}_{t-1}) + \sum_{l=1}^{2} \alpha_{2l}\bar{y}_{t-l} + \sum_{l=1}^{2} \alpha_{2(l+2)}\bar{\pi}_{t-l} \\
&\quad + \alpha_{25}Z_{t-1} + u_{\pi t},
\end{align*} \tag{63, 64} \]

where \( Z \) represents exogenous variables used as controls (see the appendix to this chapter for a detailed description); and the other variables are defined as above. There are two crucial assumptions for the estimation of the system. In the aggregate demand equation, the (lagged) real interest rate has only a direct effect on output, and its outcome on prices arises through the effect on output. Analogously, (lagged) external price inflation only affects domestic inflation contemporaneously. While the first identification assumption is often found in the literature (see, for example, Rudebusch and Svensson (1999) and the references in Taylor (2000)), the use of the second one can be justified if, as mentioned above, a change in external prices has its direct effect on domestic inflation immediately and only causes a change in domestic output after a period.\(^\text{11}\)

\(^{11}\)This would clearly be the case if the source of the external price change were an oil shock or a modification in the terms of trade that the economy faces.
Since the real interest rate only enters the dynamic aggregate demand
equation (63) and the external price inflation only enters the dynamic aggregate
supply equation (64) we can identify the parameters \( \omega, \gamma \) and \( \phi \) through
the estimation of the following vector autoregression:\(^{12}\)

\[
\tilde{y}_t = \beta_{1r}(\tilde{c}_{t-1} - \tilde{\pi}_{t-1}) + \beta_{1f}(\tilde{e}_{t-1} + \tilde{\pi}_{t-1}^e) + \sum_{i=1}^{2} \beta_{1i} \tilde{y}_{t-i} \\
\quad + \sum_{i=1}^{2} \beta_{1(t+i)} \tilde{\pi}_{t-1} + \beta_{15} Z_{t-1} + \epsilon_{yt} ,
\]

\[
\tilde{\pi}_t = \beta_{2r}(\tilde{c}_{t-1} - \tilde{\pi}_{t-1}) + \beta_{2f}(\tilde{e}_{t-1} + \tilde{\pi}_{t-1}^e) + \sum_{i=1}^{2} \beta_{2i} \tilde{y}_{t-i} \\
\quad + \sum_{i=1}^{2} \beta_{2(t+i)} \tilde{\pi}_{t-1} + \beta_{25} Z_{t-1} + \epsilon_{\pi t} .
\]

It is straightforward to show that the estimates for \( \omega, \gamma \) and \( \phi \) can be obtained
from the VAR estimation as follows:

\[
\hat{\omega} = -\frac{\beta_{1f}}{\beta_{2f}} ,
\]

\[
\hat{\gamma} = \frac{\beta_{2r}}{\beta_{1r}} ,
\]

\[
\hat{\phi} = -\beta_{1r}(1 + \hat{\omega}\hat{\gamma}) .
\]

\(^{12}\)The VAR specification is similar in spirit to the one proposed by Mojon and Peersman
(2001) for measuring the effects of monetary policy in countries of the Euro Area. The most
important differences are that we do not include US real GDP and nominal interest rate as
controls and that we estimate the same model for Austria, Belgium and the Netherlands
as for the other countries (excluding Germany).
Finally, in order to compute the policy rule parameters in equations (46) and (47), we need to obtain estimates of the variances of the aggregate shocks. We estimate the shocks using equation (59) and combining equations (56) and (60) as follows:

\[
\hat{d}_t = \frac{\bar{y}_t + \bar{\omega}\bar{\pi}_t}{\phi} + \bar{r}_t, \tag{70}
\]

\[
\hat{s}_t = \bar{\gamma}y_t - \bar{\pi}_t. \tag{71}
\]

Given the estimates for the aggregate shocks and the structural parameters - in addition to the data on inflation and output variances - we can estimate the policy rule parameters in equations (46) and (47). In the next section we present these results and proceed with the discussion of the performance and policy efficiency measures.
2.3 Results

This section is organized into three parts. First, we present our estimates of the variances of the aggregate shocks and the actual policy rule coefficients, and briefly discuss our findings. We then compare the behavior of the actual policy rule, given by the path of the nominal interest rate, with the optimal rule for the countries of interest. Finally, we report the results for the measures of macroeconomic performance and policy efficiency, and the estimates for the coefficient of aversion to inflation variability, and describe the role of monetary policy and aggregate shocks have played in accounting for the changes in macroeconomic performance.

2.3.1 Variability of Aggregate Shocks and Preferences Parameters

We begin by estimating the model (65)-(66) for the periods 1983:I-1990:IV and 1991:I-1998:IV for the 24 countries of our sample in order to the parameters \( \omega, \gamma \) and \( \phi \) for each period.\(^{13}\) For both the model specification and the derivation of the measures of performance and efficiency change we assume that policymakers are interested in achieving an inflation target of 2\% and minimize the variability of output around its potential level.\(^{14}\) While the 2\% 

\(^{13}\)The estimates of the structural parameters and the description of the variables used and data sources are presented in the appendix to this chapter.

\(^{14}\)We measure the potential level of output by fitting a log linear trend for the industrial production.
target level for inflation can be viewed as a sensible policy goal during the 1990s, it is less clear that this was the objective pursued by some countries of the area during the 1980s. However, we adopt the measure of inflation variability using this target level, since we believe a reduction in both average inflation and its variance, for a given variability of output, should be identified with an improved macroeconomic outcome.

Table 2.1 presents the estimates of the standard deviations of the aggregate shocks and the estimated preference parameter. Looking at the first two columns, we observe evidence of large cross-country differences in the variability of demand and supply perturbations. Demand shocks are particularly big for Israel, Mexico, Chile, Greece and Portugal for both periods, and are also sizable in Italy, New Zealand, Sweden, Spain, the UK and the US during the 1980s. Similar differences are present in the variability of supply shocks. We can also observe a general tendency for supply and demand shocks to become less volatile during the 1990s; only Korea, the Netherlands and Switzerland experienced an increase in the variability of demand shocks, while only Austria, Canada, Germany, Japan, Korea and Switzerland were exposed to a higher volatility of supply shocks in the 1990s.
<table>
<thead>
<tr>
<th>Country / Period</th>
<th>$\lambda$</th>
<th>$\sigma_d$</th>
<th>$\sigma_s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>0.137</td>
<td>7.55%</td>
<td>6.60%</td>
</tr>
<tr>
<td>Austria</td>
<td>0.631</td>
<td>2.40%</td>
<td>2.36%</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.850</td>
<td>3.36%</td>
<td>2.04%</td>
</tr>
<tr>
<td>Capeada</td>
<td>0.289</td>
<td>5.17%</td>
<td>3.28%</td>
</tr>
<tr>
<td>Chile</td>
<td>0.554</td>
<td>7.20%</td>
<td>3.29%</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.602</td>
<td>3.19%</td>
<td>3.99%</td>
</tr>
<tr>
<td>Finland</td>
<td>0.038</td>
<td>3.54%</td>
<td>3.70%</td>
</tr>
<tr>
<td>France</td>
<td>0.209</td>
<td>12.29%</td>
<td>18.66%</td>
</tr>
<tr>
<td>Germany</td>
<td>0.471</td>
<td>6.41%</td>
<td>3.65%</td>
</tr>
<tr>
<td>Greece</td>
<td>0.002</td>
<td>36.22%</td>
<td>4.43%</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.224</td>
<td>9.16%</td>
<td>4.29%</td>
</tr>
<tr>
<td>Israel</td>
<td>0.850</td>
<td>7.20%</td>
<td>3.99%</td>
</tr>
<tr>
<td>Italy</td>
<td>0.554</td>
<td>7.20%</td>
<td>3.99%</td>
</tr>
<tr>
<td>Japan</td>
<td>0.038</td>
<td>3.54%</td>
<td>3.70%</td>
</tr>
<tr>
<td>Korea</td>
<td>0.554</td>
<td>7.20%</td>
<td>3.99%</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.038</td>
<td>3.54%</td>
<td>3.70%</td>
</tr>
</tbody>
</table>

Table 2.1: Coefficient of Aversion to inflation Variability and Estimates of the Variability of Aggregate Shocks
<table>
<thead>
<tr>
<th>Country / Period</th>
<th>$\lambda$</th>
<th>$\sigma_d$</th>
<th>$\sigma_c$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>0.577</td>
<td>3.04%</td>
<td>1.53%</td>
</tr>
<tr>
<td>2</td>
<td>0.751</td>
<td>3.23%</td>
<td>0.78%</td>
</tr>
<tr>
<td>New Zealand</td>
<td>0.116</td>
<td>19.29%</td>
<td>9.69%</td>
</tr>
<tr>
<td>2</td>
<td>0.994</td>
<td>6.03%</td>
<td>2.87%</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.032</td>
<td>36.04%</td>
<td>17.27%</td>
</tr>
<tr>
<td>2</td>
<td>0.587</td>
<td>17.35%</td>
<td>9.01%</td>
</tr>
<tr>
<td>Spain</td>
<td>0.068</td>
<td>19.85%</td>
<td>6.87%</td>
</tr>
<tr>
<td>2</td>
<td>0.551</td>
<td>8.65%</td>
<td>2.86%</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.147</td>
<td>11.92%</td>
<td>6.13%</td>
</tr>
<tr>
<td>2</td>
<td>0.863</td>
<td>7.74%</td>
<td>3.62%</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.709</td>
<td>4.01%</td>
<td>1.84%</td>
</tr>
<tr>
<td>2</td>
<td>0.539</td>
<td>4.10%</td>
<td>2.02%</td>
</tr>
<tr>
<td>U.K.</td>
<td>0.131</td>
<td>15.05%</td>
<td>4.49%</td>
</tr>
<tr>
<td>2</td>
<td>0.612</td>
<td>5.34%</td>
<td>4.05%</td>
</tr>
<tr>
<td>U.S.</td>
<td>0.125</td>
<td>14.91%</td>
<td>7.22%</td>
</tr>
<tr>
<td>2</td>
<td>0.701</td>
<td>2.50%</td>
<td>4.37%</td>
</tr>
</tbody>
</table>

Table 2.1: Coefficient of Aversion to Inflation Variability and Estimates of the Variability of Aggregate Shocks

Turning to analyzing the preference parameters, we see that the estimates suggest a higher aversion to inflation variability in the 1990s for 21 out of the 24 countries. The only exceptions are Germany, Japan, and Switzerland. In particular, for Australia, Belgium, Finland, France, Ireland, Italy, New Zealand, Portugal, Spain, Sweden, the UK and the US this shift in the preferences has been rather sharp, consistent with the observation of a general decrease in inflation variability in the 1990s. We also note that, looking at the values of the preference parameters in the 1990s, we can sharply distinguish two subgroups of countries. For the first subgroup, composed of Chile, Greece, Israel and Mexico, the inflation aversion coefficient ranges between 0.020 for Greece and 0.189 for Chile; whereas for the remaining countries, the estimates vary from 0.535 for Italy to 0.995 for Denmark. This subdi-
vision will later be used when computing the measures of performance and efficiency changes.

Summarizing, our results suggest a general decrease of the variability of aggregate shocks in the 1990s in comparison to the 1980s, at the same time as the revealed preference suggest that policy has become more concerned with inflation stability in the last few years. As we described in Chapter 1, all countries (with the exception of Germany, Japan, Korea and Switzerland) experienced lower and more stable inflation in the 1990s, while output variability was higher in some and lower in others. A reduction in the variability of aggregate shocks, accompanied by a shift in preferences towards inflation stability, can give rise to this outcome. Still, we are interested in determining whether or not improved policy making played a role in the documented outcome, and so we proceed to this task in the next two subsections.

2.3.2 Comparing Actual and Optimal Policy Rules

As we mentioned in Section 2.2, a more efficient policy will be characterized by a policy rule that closely resembles the optimal rule. Given our estimates for the actual and optimal rule parameters and the estimates of the aggregate demand and supply shocks, we can compare the behavior of the actual and optimal policy rule for the countries in our sample, which we present in Figure 2.1.
Figure 2.1: Actual and Optimal Policy Rule (1963:I-1998:IV)
Figure 2.1: Actual and Optimal Policy Rule (1983:I-1998:IV)
Figure 2.1: Actual and Optimal Policy Rule (1983:I-1998:IV)

The comparison between the actual and optimal policy rules gives rise to some important observations. First, for most countries the optimal rule suggests that the actual policy followed by the central banks was tighter
than needed for the beginning and mid 1980s, while higher interest rates would have been advisable during the late 1980s and early 1990s. Second, the optimal rule predicts well the interest rate spikes during the crisis of the European Monetary System during late 1992 and early 1993 for Greece, Ireland and the UK, but fails to do so for Denmark, Portugal and Spain.

Another key observation that arises from Figure 2.1 is that, in general, the actual policy rule has come closer to the optimal rule after 1993. Consistent with our discussion in Section 2.2, this fact yields evidence that monetary policy has indeed become more efficient during the 1990s.

Still, a more detailed examination is needed to establish the role of monetary policy in the observed performance changes, and we proceed with this analysis in the next subsection.

2.3.3 Accounting for Changes in Macroeconomic Performance

We begin by examining the changes in performance, and then we move to report the proportion of the change that can be accounted for by improvements in policy making. As noted above, we estimate the dynamic AD-AS models and the measures of macroeconomic performance and policy efficiency for the periods 1983:I-1990:IV and 1991:I-1998:IV. Consistent with the estimates of the coefficient of aversion to inflation variability and the turn to more active stabilization of inflation in the latter half of the 1990s, we set
the value for $\lambda$ to 0.3 for Chile, Greece, Israel and Mexico and set $\lambda$ equal to 0.8 in order to compute the performance and efficiency measures.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>0.8</td>
<td>29,870</td>
<td>2,244</td>
<td>92.49%</td>
</tr>
<tr>
<td>Austria</td>
<td>0.8</td>
<td>2,982</td>
<td>2,966</td>
<td>-10.18%</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.8</td>
<td>7,668</td>
<td>1,698</td>
<td>77.86%</td>
</tr>
<tr>
<td>Canada</td>
<td>0.8</td>
<td>7,538</td>
<td>3,158</td>
<td>58.11%</td>
</tr>
<tr>
<td>Chile</td>
<td>0.8</td>
<td>551,298</td>
<td>234,497</td>
<td>57.46%</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.8</td>
<td>9,263</td>
<td>1,557</td>
<td>83.19%</td>
</tr>
<tr>
<td>Finland</td>
<td>0.8</td>
<td>15,112</td>
<td>13,874</td>
<td>7.53%</td>
</tr>
<tr>
<td>France</td>
<td>0.8</td>
<td>11,973</td>
<td>1,335</td>
<td>88.85%</td>
</tr>
<tr>
<td>Germany</td>
<td>0.8</td>
<td>2,533</td>
<td>3,083</td>
<td>-21.71%</td>
</tr>
<tr>
<td>Greece</td>
<td>0.8</td>
<td>88,169</td>
<td>34,309</td>
<td>51.09%</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.8</td>
<td>17,433</td>
<td>2,180</td>
<td>87.49%</td>
</tr>
<tr>
<td>Israel</td>
<td>0.8</td>
<td>107,473.3</td>
<td>34,709</td>
<td>99.63%</td>
</tr>
<tr>
<td>Italy</td>
<td>0.8</td>
<td>38,438</td>
<td>6,676</td>
<td>82.63%</td>
</tr>
<tr>
<td>Japan</td>
<td>0.8</td>
<td>10,424</td>
<td>9,023</td>
<td>13.44%</td>
</tr>
<tr>
<td>Korea</td>
<td>0.8</td>
<td>24,103</td>
<td>22,040</td>
<td>12.20%</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.8</td>
<td>2,645</td>
<td>1,106</td>
<td>68.17%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.8</td>
<td>69,265</td>
<td>3,186</td>
<td>95.40%</td>
</tr>
<tr>
<td>New Zealand</td>
<td>0.8</td>
<td>215,619</td>
<td>21,734</td>
<td>89.92%</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.8</td>
<td>36,766</td>
<td>7,422</td>
<td>79.81%</td>
</tr>
<tr>
<td>Spain</td>
<td>0.8</td>
<td>24,967</td>
<td>20,240</td>
<td>19.50%</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.8</td>
<td>7,544</td>
<td>4,124</td>
<td>48.33%</td>
</tr>
<tr>
<td>U.K.</td>
<td>0.8</td>
<td>15,228</td>
<td>3,461</td>
<td>77.27%</td>
</tr>
<tr>
<td>U.S.</td>
<td>0.8</td>
<td>29,591</td>
<td>2,224</td>
<td>92.48%</td>
</tr>
</tbody>
</table>

Table 2.2: Value of Loss and Performance Change

Table 2.2 reports the chosen values for $\lambda$ and the value of the loss function, $P_1$, for the 24 countries in our sample. We also report the percentage change in $P$ between the two periods for each of the countries; using the comprehensive measure of performance, only Austria and Germany exhibited a decline in performance while the other 22 countries experienced improvements. For a total of 19 countries, the performance gain ranged from 45%
in the case of Switzerland to above 99% for Israel, while only for Sweden, Japan and Korea the improvements were modest.

<table>
<thead>
<tr>
<th>Country</th>
<th>Change in policy efficiency (10,000ΔE)</th>
<th>Change in macro performance (10,000ΔP)</th>
<th>Contribution of policy to change in performance (Q=ΔE/ΔP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>22.828</td>
<td>27.626</td>
<td>0.826</td>
</tr>
<tr>
<td>Austria</td>
<td>0.537</td>
<td>-0.274</td>
<td>1.960</td>
</tr>
<tr>
<td>Belgium</td>
<td>5.731</td>
<td>5.969</td>
<td>0.960</td>
</tr>
<tr>
<td>Canada</td>
<td>2.260</td>
<td>4.380</td>
<td>0.516</td>
</tr>
<tr>
<td>Chile</td>
<td>216.067</td>
<td>316.801</td>
<td>0.682</td>
</tr>
<tr>
<td>Denmark</td>
<td>4.095</td>
<td>7.706</td>
<td>0.531</td>
</tr>
<tr>
<td>Finland</td>
<td>0.331</td>
<td>1.138</td>
<td>0.291</td>
</tr>
<tr>
<td>France</td>
<td>7.910</td>
<td>10.838</td>
<td>0.744</td>
</tr>
<tr>
<td>Germany</td>
<td>-0.446</td>
<td>-0.550</td>
<td>-0.811</td>
</tr>
<tr>
<td>Greece</td>
<td>5.928</td>
<td>53.860</td>
<td>0.110</td>
</tr>
<tr>
<td>Ireland</td>
<td>4.284</td>
<td>15.253</td>
<td>0.281</td>
</tr>
<tr>
<td>Israel</td>
<td>10638.85</td>
<td>10712.62</td>
<td>0.993</td>
</tr>
<tr>
<td>Italy</td>
<td>24.434</td>
<td>31.762</td>
<td>0.769</td>
</tr>
<tr>
<td>Japan</td>
<td>1.480</td>
<td>1.401</td>
<td>1.386</td>
</tr>
<tr>
<td>Korea</td>
<td>4.054</td>
<td>3.063</td>
<td>1.324</td>
</tr>
<tr>
<td>Mexico</td>
<td>900.02</td>
<td>2132.67</td>
<td>0.422</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.820</td>
<td>1.539</td>
<td>0.533</td>
</tr>
<tr>
<td>New Zealand</td>
<td>54.175</td>
<td>66.075</td>
<td>0.820</td>
</tr>
<tr>
<td>Portugal</td>
<td>150.681</td>
<td>193.885</td>
<td>0.932</td>
</tr>
<tr>
<td>Spain</td>
<td>21.980</td>
<td>29.344</td>
<td>0.739</td>
</tr>
<tr>
<td>Sweden</td>
<td>8.920</td>
<td>4.747</td>
<td>1.879</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.839</td>
<td>3.420</td>
<td>0.245</td>
</tr>
<tr>
<td>U.K.</td>
<td>10.557</td>
<td>11.765</td>
<td>0.897</td>
</tr>
<tr>
<td>U.S.</td>
<td>21.950</td>
<td>27.367</td>
<td>0.862</td>
</tr>
</tbody>
</table>

Table 2.3: Estimates of the Measures

Table 2.3 reports the estimates of the performance change ΔP, improved policy efficiency, ΔE, and the proportion of performance change that is due to a change in the efficiency of policy, Q. We see that all countries - except for Germany - experienced improvements in the efficiency of monetary policy. In the case of the European Union Countries, these observed improvements
are likely linked to the desire to meet the qualification requirements for the Monetary Union, while the decline observed in Germany is almost surely the consequence of both unification and the necessary adjustment prior to its entry into the EMU. We note, however, that the deterioration in German performance and policy efficiency was fairly modest over this period.

We can also observe that in the case of Austria more efficient policy was present despite the measured macro performance loss, while for Japan, Korea and Sweden, policy efficiency gain was higher than the macro performance improvement. This is consistent with the observation that these four countries were exposed to either (or both) more volatile demand and supply shocks during the 1990s. Looking at the final column, for the remaining 19 countries that experience both improved performance and better policy, more efficient policy accounted for between 11% (Greece) and 99% (Israel) of the improvement in overall macroeconomic performance.

Overall, within the 22 countries that experienced a macro performance improvement, in 8 cases - Greece, Switzerland, Ireland, Finland, Mexico, Canada, Denmark and the Netherlands - a lower variability of the shocks played a role as important or more so than better policy, whereas for the 14 remaining countries - Chile, Spain, France, Italy, the US, the UK, New Zealand, Australia, Portugal, Belgium, Israel, Korea, Japan and Sweden - more efficient policy played a far more important role than the reduced variability of shocks in macroeconomic stabilization.
<table>
<thead>
<tr>
<th>Country</th>
<th>Macroeconomic Performance Gain (in %)</th>
<th>Contribution of policy to change in performance (Q=Δε/ΔP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>[91.2%, 93.4%]</td>
<td>[0.578, 0.977]</td>
</tr>
<tr>
<td>Austria</td>
<td>[-26.8%, 14.2%]</td>
<td>[-6.624, 5.663]</td>
</tr>
<tr>
<td>Belgium</td>
<td>[63.6%, 89.8%]</td>
<td>[0.927, 0.989]</td>
</tr>
<tr>
<td>Canada</td>
<td>[52.4%, 54.0%]</td>
<td>[0.507, 0.752]</td>
</tr>
<tr>
<td>Chile</td>
<td>[56.0%, 58.6%]</td>
<td>[0.546, 0.711]</td>
</tr>
<tr>
<td>Denmark</td>
<td>[70.8%, 94.8%]</td>
<td>[0.277, 0.853]</td>
</tr>
<tr>
<td>Finland</td>
<td>[-21.5%, 28.1%]</td>
<td>[0.112, 0.442]</td>
</tr>
<tr>
<td>France</td>
<td>[81.5%, 94.3%]</td>
<td>[0.578, 0.937]</td>
</tr>
<tr>
<td>Germany</td>
<td>[-42.1%, -8.3%]</td>
<td>[-1.223, -0.583]</td>
</tr>
<tr>
<td>Greece</td>
<td>[61.0%, 61.2%]</td>
<td>[0.048, 0.252]</td>
</tr>
<tr>
<td>Ireland</td>
<td>[79.5%, 94.4%]</td>
<td>[0.182, 0.597]</td>
</tr>
<tr>
<td>Israel</td>
<td>[99.5%, 99.7%]</td>
<td>[0.884, 0.996]</td>
</tr>
<tr>
<td>Italy</td>
<td>[79.8%, 84.6%]</td>
<td>[0.574, 0.947]</td>
</tr>
<tr>
<td>Japan</td>
<td>[4.2%, 25.9%]</td>
<td>[0.151, 6.017]</td>
</tr>
<tr>
<td>Korea</td>
<td>[-20.1%, 45.7%]</td>
<td>[-0.022, 3.979]</td>
</tr>
<tr>
<td>Mexico</td>
<td>[92.6%, 93.5%]</td>
<td>[0.135, 0.597]</td>
</tr>
<tr>
<td>Netherlands</td>
<td>[49.4%, 69.5%]</td>
<td>[0.532, 0.797]</td>
</tr>
<tr>
<td>New Zealand</td>
<td>[92.1%, 97.8%]</td>
<td>[0.724, 0.902]</td>
</tr>
<tr>
<td>Portugal</td>
<td>[88.2%, 91.1%]</td>
<td>[0.856, 0.990]</td>
</tr>
<tr>
<td>Spain</td>
<td>[74.9%, 83.3%]</td>
<td>[0.523, 0.935]</td>
</tr>
<tr>
<td>Sweden</td>
<td>[5.9%, 36.8%]</td>
<td>[0.072, 3.014]</td>
</tr>
<tr>
<td>Switzerland</td>
<td>[33.5%, 63.4%]</td>
<td>[-0.156, 0.600]</td>
</tr>
<tr>
<td>U.K.</td>
<td>[74.3%, 79.5%]</td>
<td>[0.888, 0.932]</td>
</tr>
<tr>
<td>U.S.</td>
<td>[91.4%, 93.3%]</td>
<td>[0.706, 0.822]</td>
</tr>
</tbody>
</table>

Table 2.4: Performance and Efficiency Changes over a range of values for inflation aversion

As a last robustness check, we are interested in studying what happens to our measures for policy efficiency and performance change over a range for plausible values of λ. For the countries for which we set our baseline estimates λ equal to 0.8, we consider a range of 0.65 to 0.95. This is consistent with the estimates obtained by in the previous section. For the four high inflation countries, where the baseline value of λ was set to 0.3, we consider a range between 0.15 and 0.45 for λ, for the reasons detailed above. In the first
column of Table 2.4 we observe that the range for the measure of performance gain is relatively narrow and centered at the value of their estimate. Only in the cases of Austria and Korea do the ranges suggest that there could be either a performance gain or a loss between both periods. As for the relative contribution of policy, the range of possible values is quite large for some countries, mostly Austria, Japan, Korea, Sweden and Switzerland. Despite this fact, the ranges on the contribution of policy to the performance gain still point to an important role of monetary policy in contributing to a macroeconomic performance improvement in most of the analyzed countries.

Summarizing, our main findings suggest that in 58% of the countries, policy was the driving force behind macroeconomic stabilization, whereas in 33% of the cases a lower variability of the shocks also played an important role. Only in the case of Germany was policy less efficient, while in Austria, better policy was able to partially offset the increased variability of the shocks.
2.4 Conclusions

This chapter proposes a general methodology for analyzing changes in macroeconomic performance and identifying the relative contributions of improvements in the efficiency of monetary policy and changes in the variability of aggregate shocks. We apply this technique to 24 industrialized and developing countries in order to compare their macroeconomic performance in the 1980s with that in the 1990s.

We find that, in general, the actual policy followed by the monetary authorities has come closer to the optimal rule during the 1990s. Our results suggest that in all countries but Germany monetary policy became more efficient in the last decade, as compared to the 1980s. The evidence regarding the importance of a reduced variability in the aggregate shocks as a source of performance improvements is somewhat mixed: for eight countries it was nearly as or more important as more efficient policy in stabilization, while for the remaining countries the change in the volatility of the shocks either played a minor role or contributed towards a deterioration of macroeconomic performance (for Austria and Germany).
CHAPTER 3

MONETARY POLICY EFFICIENCY AND THE VARIABILITY FRONTIER\textsuperscript{15}

3.1 Introduction

The purpose of this chapter is to present an alternative method for measuring the contribution of improved monetary policy to observed changes in macroeconomic performance and use it to explain the observed increase in macroeconomic stability in a cross-section of countries. Our technique involves examining changes in the variability of inflation and output over time. We estimate a simple macroeconomic model of inflation and output for each country, and use it to construct an output-inflation variability efficiency frontier. Specifically, for each country we specify the dynamics of inflation and output as a function of the interest rate – our measure of the central bank policy instrument – as well as additional exogenous variables. Using the estimated model, we are able to compute the output-inflation efficiency frontier as the solution to a simple optimization problem in which policymakers are

\textsuperscript{15}This chapter is largely based on a joint paper with Stephen G. Cecchetti and Alfonso Flores-Lagunes, “Has Monetary Policy Become More Efficient? A Cross-Country Analysis”.

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assumed to minimize a loss function that is a weighted average of the squared deviations of inflation and output from their target levels.

We estimate this frontier for two sample periods, the 1980s and the 1990s. Next, we compute the change in macroeconomic performance for each country using a weighted sum of inflation and output volatility, and examine how much of that change can be accounted for by a movement in the variability frontier, and how much is a movement toward the frontier itself. Shifts in the variability frontier are ascribed to changes in the volatility of supply shocks, while movements toward the frontier are a measure of improvements in policy efficiency. Our calculations allow us to parse improvements in macroeconomic performance into the portion that can be accounted for more efficient policy and the part that can be attributed to lower supply shock variability.

The remainder of the chapter is divided into five sections. In Section 3.2 we introduce the proposed methodology to analyze the changes in macroeconomic performance. Section 3.3 describes the procedure to obtain the efficiency frontier for monetary policy using a linear structural model that captures the dynamics of each of the economies in question. Section 3.4 presents and discusses the main results. Our results suggest that improved monetary policy has played a stabilization role in 20 of the 24 countries. Seventeen countries experienced reduced supply shock variability, but overall this had a modest impact on performance. Section 3.5 discusses some explanations for the cross-country differences we encounter in the changes in macroeconomic
performance and monetary policy efficiency, while Section 3.6 concludes the chapter.
3.2 Measuring the Sources of Performance Changes

Our goal is to divide changes in macroeconomic performance into the portion that is due to changes in the variability of shocks and the part that can be ascribed to changes in policy efficiency. To do this, we rely on the use of the inflation-output variability trade-off, or efficiency frontier. As we explain, increases or decreases in the variance of supply shocks shifts this frontier, while movements toward or away from the trade-off arise from improvements or declines in policy efficiency. Since our measures can be derived using a simple two-dimensional graph, we begin with an intuitive explanation. Section 3.3 contains analytical derivations that are based on a specific, and empirically tractable, macroeconomic model.

The concept of an inflation-output variability frontier is easiest understood by considering a simple economy that is affected by two general types of disturbances, both of which may require policy responses. These are aggregate demand shocks – which move output and inflation in the same direction – and aggregate supply shocks – which move output and inflation in opposite directions. Since monetary policy can move output and inflation in the same direction, it can completely offset aggregate demand shocks. By contrast, aggregate supply shocks will force the monetary authority to face a trade-off between the variability of output and that of inflation.\textsuperscript{16}

\textsuperscript{16}For a simple algebraic model and a discussion of the derivation of the output-inflation

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This trade-off allows us to construct an efficiency frontier for monetary policy that traces the points of minimum inflation and output variability. This is the curved line in Figure 3.1, known in the literature as the Taylor Curve (Taylor, 1979). The location of the efficiency frontier depends on the variability of aggregate supply shocks - the smaller such variability, the closer the frontier will be to the origin. If monetary policy is optimal, the economy will be on this curve. The exact point depends on the policymaker's preferences for inflation and output stability. When policy is sub-optimal, the economy will not be on this frontier. Instead, the performance point will be up and to the right, with inflation and output variability both in excess variability frontier see Cecchetti and Ehrmann (2001).
of other feasible points. Movements of the performance point toward the frontier are an indication of improved policymaking.

Our goal is to measure both movements in the performance point and shifts in the policy efficiency frontier. In order to obtain a summary measure of performance, we assume that the objective of policymakers is to minimize a weighted sum of inflation and output variability. Just as we did in Chapters 1 and 2, we can summarize this loss as:

$$\text{Loss} = \lambda \text{Var}(\pi) + (1 - \lambda)\text{Var}(y), \ 0 \leq \lambda \leq 1$$

(72)

where $\pi$ is inflation, $y$ is output, and $\lambda$ is the policymaker’s preference parameter – Cecchetti and Ehrmann (2001) call this the policymaker’s inflation variability aversion. We will assess an economy’s performance, and changes in macroeconomic outcomes, using estimates based on this loss. Obviously, computation of the loss requires an estimate of the preference parameter $\lambda$. We defer discussion of how $\lambda$ is determined until Section 4.3. For the time-being, we will assume that $\lambda$ is known.

Given the policymaker’s preferences, we can define the scalar measures of changes in performance, changes in policy efficiency and changes in the variance of supply shocks that we will use in our empirical analysis. First, macroeconomic performance is simply a weighted average of the observed variances of output and inflation. Analogous to our definition in Chapter 2, we call this $P_i$ ($i = 1, 2$; periods), and define it as:
\[ P_t = \lambda Var(\pi_t) + (1 - \lambda) Var(y_t). \]  

(73)

The change in macroeconomic performance is just the change in \( P \) from one period to the next, \( \Delta P = P_1 - P_2 \). If \( \Delta P \) is positive we interpret this as a performance gain. To allow for a proper comparison across periods, when computing \( \Delta P \) we assume \( \lambda \) to be constant.

This change in performance reflects both shifts in the variability frontier, and toward or away from the frontier. We identify shifts in the efficiency frontier by measuring changes in the weighted sum of the optimal variances of output and inflation. Since the efficiency frontier shifts if and only if the variability of supply shocks changes, we refer to this as our measure of the variability of supply shocks, and it is given by:

\[ S_i = \lambda Var(\pi_i)^* + (1 - \lambda) Var(y_i)^* \]  

(74)

where \( Var(\pi_i)^* \) and \( Var(y_i)^* \) are the variances of inflation and output under optimal policy for period \( i \), respectively. \( \Delta S = S_2 - S_1 \) is the measure we use to quantify the change in the variability of supply shocks. We define \( \Delta S \) in this fashion, instead of the one we employ to define \( \Delta P \), so that we can interpret negative values of \( \Delta S \) as an indicator that the shocks hitting the economy have been smaller in absolute value, and conversely.
To estimate $Var(\pi_i)^*$ and $Var(y_i)^*$ we use the following procedure. Beginning with Figure 3.1, we shift the efficiency trade-off homothetically outward until it passes through the performance point representing the observed variances of inflation and output. Figure 3.2 shows the original and shifted frontiers. We define the optimal variances as the point on the original frontier associated with this same performance point. In Section 3.3 we describe the derivation of the optimal variance point analytically. A geometrical interpretation of the optimal variance is the intersection point of the original frontier with a line from the origin to the performance point.
Once again, as we did in Chapter 2, we gauge monetary policy efficiency by looking at the distance between actual performance and performance under optimal policy. Policy inefficiency for each period is given by:

\[ E_i = \lambda[\text{Var}(\pi_i) - \text{Var}(\pi_i^*)] + (1 - \lambda)[\text{Var}(y_i) - \text{Var}(y_i^*)] \]  

(75)

The definitions of \( P_i \) and \( S_i \) imply that \( E_i \) can be also obtained as the difference \( P_i - S_i \). Since \( E_i \) will be smaller the closer actual outcomes are to the optimal, our measure of the change in policy efficiency follows immediately as the difference \( \Delta E = E_1 - E_2 \). We interpret positive values of \( \Delta E \) as increases in the efficiency of monetary policy. When \( \Delta E \) is negative, it suggests that policymaking has deteriorated as the economy has moved further away from the frontier.

Finally, we employ once more the division of the change in performance into its two components to calculate the proportion that can be accounted for by improved policy. The measure we use is given by the following ratio:

\[ Q = \frac{\Delta E}{|\Delta P|} \]  

(76)

Given that the absolute value of the performance gain is in the denominator, a positive value of \( Q \) implies improved policy efficiency, whereas a negative \( Q \) implies that policy has become less efficient. If we observe a macro performance gain at the same time as policy has become more efficient and the variance of supply shocks has become smaller, \( Q \) will be between 0 and 1.
and can be interpreted as the relative contribution of a more efficient policy
towards the achievement of a macro performance gain.

Implementing the procedure we have just described requires us to follow
several steps. First we must construct and estimate a dynamic model of
inflation and output for each of countries for the periods we are interested
in. Then, using these estimates and an unrestricted policy rule represented
by the interest rate (the policymakers instrument), we can construct each
period's efficiency frontier and performance point. With these in hand and
assuming plausible values of the preference parameter \( \lambda \), we are then able
to compute \( \Delta P, \Delta S, \Delta E, \) and \( Q \). This is the task of the remainder of the
chapter.
3.3 Estimating the Efficiency Frontier

The efficiency frontier is constructed as follows. Beginning with the quadratic loss function representing tradeoffs among combinations of inflation and output variability, we treat policy as a solution to an optimal control problem in which the interest rate path is chosen to place the economy at the point on the variability frontier that minimizes the loss. Formally, we compute the policy reaction function that minimizes the loss, subject to the constraint that is imposed by the structure of the economy. For a given loss function, with a particular weighting of inflation and output variability (\( \lambda \)), we are able to plot a single point on the efficiency frontier. As we change the relative weight assigned to the variance of inflation and output in the loss function, we are able to trace out the entire efficiency frontier.

Our econometric procedure has four steps. First, in Section 3.3.1, we estimate simple structural models of inflation and output for each of the 24 countries in our sample. Next, in Section 3.3.2 we undertake a number of diagnostic and specification checks to establish the adequacy of empirical models. In Section 3.3.3 we describe the construction of the efficiency frontier from the model estimates. Finally, in Section 3.3.4 we describe a simulation-based approach to assess the reliability of the estimated measures.
3.3.1 Structural Model

Parsimony is an important consideration in choosing a specification to approximate the dynamics of the economies under consideration. As a result, we build models that satisfy a minimal set of key conditions. First, the model should be general enough so that it can be estimated, with only minor changes, for all of the 24 countries in the sample. Second, the model should fit the data reasonably well and yield theoretically plausible estimates to be used in the construction of the efficiency frontier. Finally, the model must be simple enough so that we can apply simulation techniques to evaluate the reliability of the quantities of interest.

With these requirements in mind, we consider linear two-equation systems for each country based on a dynamic aggregate demand - aggregate supply model. The basic model consists of the following two equations:

\[
y_t = \sum_{l=1}^{2} \alpha_{11}i_{t-l} + \sum_{l=1}^{2} \alpha_{1(l+2)}y_{t-l} + \sum_{l=1}^{2} \alpha_{1(l+4)}\pi_{t-l-1} + \alpha_{17}x_{t-1} + \varepsilon_{1t} \tag{77}
\]

\[
\pi_t = \sum_{l=1}^{2} \alpha_{21}y_{t-l-1} + \sum_{l=1}^{2} \alpha_{2(l+2)}\pi_{t-l} + \alpha_{25}x_{t-1} + \varepsilon_{2t} \tag{78}
\]

The first equation represents an aggregate demand curve. It relates detrended log industrial production, \(y\), to two of its own lags, two lags of the nominal interest rate, \(i\), two lags of demeaned inflation, \(\pi\), and one lag of demeaned external price inflation, \(x\). The second equation is an aggregate supply curve. Here, inflation is assumed to be a function of two of its own
lags, representing inflation expectations, two lags of detrended log industrial production and one lag of demeaned external price inflation. The error terms $\varepsilon_1$ and $\varepsilon_2$ are assumed to be mean zero and constant variance.

This model is a two-lagged vector autoregressive (VAR) model with three endogenous variables (inflation, industrial production and interest rates) and the restriction that interest rates do not enter into the inflation equation.\(^{17}\) This formulation is based on the empirical observation that monetary policy actions affect industrial production before inflation (see, for instance, the empirical model in Rudebusch and Svensson (1999) and the theoretical model of Svensson (1997), among others). We formally test this restriction in the next section and find statistical evidence supporting it.

We estimate equations (77) and (78) for each country separately using ordinary least squares (OLS). In some cases we also included dummy variables to account for currency crises, sharp recessions, or structural changes. A description of the variables used for each country is included in Appendix I. Appendix II lists all of the data sources.

### 3.3.2 Diagnostic and Specification Analysis

In this section we undertake a series of diagnostic and specification tests of our two-equation structural model. We begin by discussing the time-series

\(^{17}\)We estimate below an additional equation for the interest rate that contains lags of all endogenous variables in order to obtain impulse response functions (IRFs). However, we only need the estimates of the two-equation model in (77) and (78) to obtain the efficiency frontier.
properties of our data, and then move on to a comparison of the restricted model to a more general one that encompasses it.

Our first test of model adequacy is to establish that the estimated residuals are independent. Autocorrelation would be evidence of misspecification. Using a Durbin-h test applied to the residuals of the two-equation model (estimated for both periods and all countries using OLS) we are unable to reject the null hypothesis of no autocorrelation at a 10% level or higher for all of the countries in our sample.\(^{18}\)

For the derivation of the efficiency frontier and the application of the simulation method proposed below to assess the reliability of the estimated measures, it is necessary that the residuals be stationary. This requires either that the demeaned, detrended endogenous variable be stationary themselves, or that there exists some cointegrating relationship among them. Since the distinction between these two is immaterial to us, we simply test for the non-stationarity of the estimated residuals. Using the Phillips-Perron (1988) test we are able to reject the null hypothesis of non-stationarity at the 1% significance level in all countries for both periods. This is strong support for the compatibility of our model specification with the integration properties of the data.

\(^{18}\)The only exceptions are the output equation for the first period in the case Belgium, for which the p-value of the Durbin-h test is 0.081, and the inflation equation for the first period in the case of Mexico, for which the p-value of the Durbin-h test is 0.096.
Since we are estimating a system of two equations separately, there might exist some cross correlation between the error terms of the equations that can be exploited to obtain more efficient estimators with a system estimator such as seemingly unrelated regressions (SUR). To check whether the separate estimation of each equation is efficient relative to system estimation, we tested the contemporaneous correlation of the error terms of the two-equation model for each period in each of the countries in our sample. We were not able to reject the null hypothesis of zero contemporaneous correlation at a 10% level or higher in both periods for all countries with the exception of two. In these cases, we are not able to reject the null hypothesis at the 5% and 1% levels.\textsuperscript{19} This provides justification for the single-equation estimation of the model.

We next test the specification of our structural model by testing the restrictions that it imposes on an unrestricted vector autoregressive (VAR) model. In an unrestricted VAR, the right-hand-side variables in both regressions would be identical, with the number of lags on each regressor, and the regressors themselves, being the same. Relative to a general unrestricted setup, our model omits the interest rate from the right-hand-side of the supply equation (78).

\textsuperscript{19}Chile in the first subperiod has a p-value of 0.016; while Denmark in the second subperiod has a p-value of 0.044; however, in neither of these cases are the SUR coefficients and standard errors significantly different from the ones obtained through the OLS estimation.
We compare our models with the corresponding unrestricted VAR models based on three different criteria. First, we test the restriction using standard (exact) F and (asymptotic) Lagrange Multiplier (LM) statistics. Next, we provide two more comparisons, one based on the theoretical plausibility of the Impulse Response Functions (IRFs) yielded by each model, and the other based on model selection criteria such as the Akaike and Bayesian information criteria (AIC and BIC, respectively). The IRFs show the response function of inflation to a change of 100 basis points in the interest rate. To be able to compare the IRFs yielded by the two models, we add an identical interest rate equation to each of them, which results in IRFs that will only differ due to the restrictions imposed in the equation for inflation in the structural model.\footnote{The impulse response functions and the summary statistics for the diagnostics tests are available upon request from the authors.}

Beginning with the VAR comparison, we find that, with the exception of Australia and Switzerland, the restrictions implied in the inflation equation of the structural model are not rejected by either the F or the LM tests for the first period at a significance level of 5% or higher.\footnote{In fact, for 19 countries the p-value of both tests is above 0.10.} Nevertheless, restricting the coefficients on the lagged interest rate to zero for these two countries actually yields more sensible IRFs of inflation.\footnote{The IRFs and the AIC and SIC criteria are not presented here in order to save space but they are available from the authors upon request.} For the second period, 14 countries fail to reject the restrictions at a 5% level or more, while for the rest
the restrictions are rejected by at least one of the tests.\textsuperscript{23} With the exception of two countries (Switzerland and the US), restricting the coefficients on the lagged interest rate to zero in the inflation equation eliminates the so-called price-puzzle (Sims, 1992) in the IRFs, whereas for Switzerland and the US, the price-puzzle is less pronounced under the structural model.\textsuperscript{24} We regard this as evidence that our structural model is correctly specified.

Finally, we also evaluate the goodness of fit of our proposed model by using the Akaike and Bayesian information criteria (AIC and BIC). These two model selection criteria are functions of the residual sum of squares of the models and differ in the degree to which they penalize the estimation of extra parameters, with the BIC penalty being higher. Given the small number of degrees of freedom resulting from the estimation in each period, we consider the BIC is a better criterion for comparing the two models. When looking at each country in each of the two periods, the BIC criteria tends to favor our structural specification over an unrestricted VAR. Considering both information criteria together, for 13 countries the structural model is supported over the VAR specification.\textsuperscript{25} Apart for only 4 countries where the VAR is favored, in the remaining 7 the evidence is mixed. In sum, the restrictions implied by the structural model do not seem inadequate.

\textsuperscript{23}These countries are Australia, Canada, Denmark, Germany, Korea, Netherlands, New Zealand, Spain, Switzerland and the U.S.

\textsuperscript{24}A rise in inflation following an increase in the nominal interest rate is commonly referred to as the \textit{price puzzle}.

\textsuperscript{25}Among the 13 countries are Korea and Netherlands, for which the restrictions where rejected for the second period.
Overall, we interpret the evidence as supporting the restrictions imposed by the structural model vis-a-vis the overparametrized VAR model, and therefore supporting the specification of the structural model. In the following section, we use the model in (77) and (78) to construct the efficiency frontier, which will be then used to compute the measures of interest.

### 3.3.3 Constructing the Efficiency Frontier

With estimates of the structural model in hand, we turn to the construction of the efficiency frontier. As described above, we derive the frontier by minimizing an objective function subject to the constraints imposed by the dynamic structure of the economy.

To begin, we assume that the central bank chooses an interest rate path to minimize a weighted average of the squared deviations of inflation and output from some target values. Consistent with the definition of the loss function in (72), we write this as:

\[
E[L] = E \left[ \lambda (\pi_t - \pi^*)^2 + (1 - \lambda) (y_t - y^*)^2 \right],
\]

(79)

where \(\pi^*\) and \(y^*\) are the policymaker's targets for inflation and output, respectively.\(^{26}\)

\(^{26}\)This loss function does not include the exchange rate or the interest rate, since we assume that the fundamental concern of a central bank is domestic macroeconomic performance as measured by output and price stability.

\(^{27}\)We assume that the inflation target for all countries is 2%, and that monetary authorities want to keep industrial production as close as possible to its log linear trend, computed by applying the H-P filter. We explore the robustness of our results to different targets in the next section.
For the purposes of exposition, it is useful to rewrite the basic structural model in (77)-(78) in its state-space representation,

\[
Y_t = BY_{t-1} + ci_{t-1} + DX_{t-1} + v_t
\]  
(80)

where: \( Y_t = \begin{bmatrix} i_{t-1} \\ y_t \\ y_{t-1} \\ \pi_t \\ \pi_{t-1} \end{bmatrix} \); \( B = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 \\ \alpha_{12} & \alpha_{13} & \alpha_{14} & \alpha_{15} & \alpha_{16} \\ 0 & 1 & 0 & 0 & 0 \\ 0 & \alpha_{21} & \alpha_{22} & \alpha_{23} & \alpha_{24} \\ 0 & 0 & 0 & 1 & 0 \end{bmatrix} \); 

\[
c = \begin{bmatrix} 1 \\ \alpha_{11} \\ 0 \\ 0 \\ 0 \end{bmatrix} \); \( D = \begin{bmatrix} 0 \\ \alpha_{17} \\ 0 \\ \alpha_{25} \\ 0 \end{bmatrix} \); \( X_t = [px_t ] \); \( v_t = \begin{bmatrix} \varepsilon_{1t} \\ 0 \\ \varepsilon_{2t} \\ 0 \end{bmatrix} \)

The policymaker’s problem is to choose a path for the interest rate, \( i_t \), in order to minimize (79), subject to the constraints imposed by (80). The linear-quadratic nature of the problem ensures that the solution for the control, the interest rate, will be linear. We write this as:

\[
i_t = \Gamma Y_t + \Psi \]  
(81)

where \( \Gamma \) is the vector of reaction coefficients of the monetary authority to inflation and output changes and \( \Psi \) is a constant term which depends on \( B, c, D \) and the target values for inflation and output.\(^{28}\) Equation (81) represents an unrestricted monetary policy rule.\(^{29}\)

\(^{28}\)See Chow (1975), pp. 158-159.

\(^{29}\)See Rudebusch and Svensson (1999).
The control problem is solved by finding $\Gamma$ such that:

$$\Gamma = -(d'Hc)^{-1}d'Hb$$

(82)

and

$$H = \Lambda + (B + c\Gamma)'H(B + c\Gamma)$$

(83)

where $\Lambda$ is an 5x5 matrix containing the relative weights given to output and inflation variance on the second and fourth diagonal elements, respectively, and zeros elsewhere.

Following this procedure once for a given value of $\lambda$ provides us with a single point on the efficient frontier. By varying $\lambda$ we are able to trace out an entire curve similar to the one in Figure 3.1.

Given this estimate of the efficiency frontier, as we explained in Section 3.2, we perform a homothetic shift of the frontier so that it passes through the data point given by the observed variances of inflation and output. This point will be associated with a certain value for $\lambda$. The estimate of the optimal variances of inflation and output will be given by the point on the original frontier that results from that value of $\lambda$.

We use the estimated efficiency frontier to obtain the measures of interest presented in Section 3.2. These measures (to be reported in Section 3.4) are simply estimates and not the true values of the quantities of interest. For this

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30 For a technical exposition of this procedure see Chow (1975), pp. 156-160.
reason, in the next section, we describe the methodology we use to evaluate their reliability as estimates of the true measures.

3.3.4 Assessing the Reliability of the Measures

The main hurdle we face in evaluating the reliability of our measures is that the typical statistical tools (such as the Delta method) are difficult to apply, given that our estimates result from a nonlinear dynamic optimization procedure. To overcome this problem we use simulation methods to construct an empirical distribution for the estimated measures. Specifically, we employ the parametric recursive bootstrap (Freedman and Peters, 1984) to obtain a number of “pseudo” samples for each country. These samples are used to compute replications of the measures and thus construct their empirical distributions.

The recursive bootstrap used here assumes that the estimated model for each country in equations (77) and (78) is correctly specified, and that the corresponding error terms are independent but not identically distributed (inid). This two assumptions are sufficient conditions to apply the parametric recursive bootstrap. In Section 3.3.2, we provided some evidence about the validity of our specification by comparing it to a more general model (the unrestricted VAR). In addition, the inid assumption is satisfied by the stationarity and lack of serial correlation in the estimated residuals (see Section 3.3.1).
We resample with replacement from the matrix consisting of both estimated residuals from both equations of the structural model. The bootstrap sample of industrial production and inflation is obtained in a recursive fashion assuming the other variables in the model and the initial values of both industrial production and inflation are given (i.e. we use their original values). Finally, we iterate this process a number of times to obtain replications for the measures.\footnote{For a detailed discussion of the procedure see Li and Maddala (1996).}

We obtain 1,000 bootstrap samples and estimate the structural model, the efficiency frontier, and the measures of interest. The replications of the measures are used to median-correct the estimated measures. The median correction is performed to obtain more robust estimates of the central tendency parameter of the corresponding distributions;\footnote{In general, a median corrected estimator is obtained with the following formula:}

\[ \hat{\beta}_{MC} = 2\hat{\beta} - \hat{\beta}_{median} \]

where \( \hat{\beta} \) is the original estimator and \( \hat{\beta}_{median} \) is the median obtained from the empirical distribution yielded by the bootstrap.\footnote{The sizes of the median corrections are available upon request from the authors.}
3.4 Results

We examine our results in two steps. First we look at performance changes themselves, and then we report the proportion of the change that can be accounted for by improvements in policymaking.

3.4.1 Performance Changes

We estimate models and frontiers for 24 countries over two sample periods, 1983:I-1990:IV and 1991:I-1998:IV. Analogous to our discussion in Chapter 2, in order to measure inflation and output variability, we assume that policymakers are interested in achieving an inflation target of 2% and in minimizing the variability of output around its potential level, as measured by a Hodrick-Prescott-filtered trend of industrial production. While the 2% target level for inflation can be viewed as a sensible policy goal during the 1990s, it is less clear that this was the objective pursued by some countries during the 1980s. Still, we adopt the measure of inflation variability using this target level, since we believe a reduction in both average inflation and its variance, for a given variability of output, should be identified with an improved macroeconomic outcome.
We note, however, that our results are robust to using the country's average inflation and an H-P filtered series for inflation as targets instead of the 2% target.\(^{34}\,^{35}\)

Before computing the measures introduced in Section 3, we require an estimate of the preference parameter \(\lambda\). Our approach is to consider a set of plausible values of \(\lambda\) for each of the analyzed countries based on the estimates obtained elsewhere by Cecchetti and Ehrmann (2001) and Krause (2002). This procedure means that we do not have to identify a single value of this parameter for each individual country. In the following section, we show that our results are robust to this choice.

With this in mind, Table 3.1 reports the value chosen for the inflation variability aversion coefficients and the value of the loss function, \(P_t\), for the 24 countries in our sample, as well as the percentage change in \(P\) between the two periods for each of the countries. We set \(\lambda\) equal to 0.8 for all countries, with the exception of Israel, Mexico, Chile and Greece, for which we choose a values of 0.3. These four countries experienced very high levels of inflation during the 1980s, suggesting that inflation variability must have had a much lower weight in the policymaker's loss function.

\(^{34}\)In a previous version of the paper we also considered a log-linear trend for industrial production as the target level for output, which yields almost identical results as the ones obtained using the H-P filtered series.

\(^{35}\)The estimates of the measures with alternative targets for inflation and output are available upon request from the authors.
Turning to the results, we see in Table 3.1 that, using our comprehensive measure of performance, only Austria, Germany and Finland exhibited a slight decline in performance while 16 countries experienced sizable improvements. These ranged from 50% for Canada to over 99% for Israel. We estimate that performance in Korea and Sweden improved by less than 10%.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>0.8</td>
<td>32.780</td>
<td>2.175</td>
<td>93.37%</td>
</tr>
<tr>
<td>Austria</td>
<td>0.8</td>
<td>3.023</td>
<td>4.914</td>
<td>-35.63%</td>
</tr>
<tr>
<td>Belgium</td>
<td>0.8</td>
<td>9.149</td>
<td>3.012</td>
<td>67.08%</td>
</tr>
<tr>
<td>Canada</td>
<td>0.8</td>
<td>11.324</td>
<td>5.655</td>
<td>50.06%</td>
</tr>
<tr>
<td>Chile</td>
<td>0.3</td>
<td>553.370</td>
<td>246.248</td>
<td>55.50%</td>
</tr>
<tr>
<td>Denmark</td>
<td>0.6</td>
<td>11.382</td>
<td>3.325</td>
<td>70.79%</td>
</tr>
<tr>
<td>Finland</td>
<td>0.8</td>
<td>14.642</td>
<td>16.304</td>
<td>-11.36%</td>
</tr>
<tr>
<td>France</td>
<td>0.8</td>
<td>12.857</td>
<td>2.320</td>
<td>81.95%</td>
</tr>
<tr>
<td>Germany</td>
<td>0.8</td>
<td>4.164</td>
<td>4.729</td>
<td>-13.50%</td>
</tr>
<tr>
<td>Greece</td>
<td>3.3</td>
<td>93.360</td>
<td>36.196</td>
<td>61.23%</td>
</tr>
<tr>
<td>Ireland</td>
<td>0.8</td>
<td>19.665</td>
<td>7.161</td>
<td>63.69%</td>
</tr>
<tr>
<td>Israel</td>
<td>0.3</td>
<td>10768.85</td>
<td>43.60</td>
<td>99.60%</td>
</tr>
<tr>
<td>Italy</td>
<td>0.8</td>
<td>40.340</td>
<td>6.892</td>
<td>82.52%</td>
</tr>
<tr>
<td>Japan</td>
<td>0.8</td>
<td>11.254</td>
<td>8.804</td>
<td>21.85%</td>
</tr>
<tr>
<td>Korea</td>
<td>0.6</td>
<td>26.296</td>
<td>24.149</td>
<td>8.89%</td>
</tr>
<tr>
<td>Mexico</td>
<td>0.3</td>
<td>2269.62</td>
<td>160.035</td>
<td>93.01%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0.8</td>
<td>2.728</td>
<td>1.287</td>
<td>53.69%</td>
</tr>
<tr>
<td>New Zealand</td>
<td>0.8</td>
<td>73.419</td>
<td>10.588</td>
<td>86.58%</td>
</tr>
<tr>
<td>Portugal</td>
<td>0.8</td>
<td>218.901</td>
<td>25.981</td>
<td>88.13%</td>
</tr>
<tr>
<td>Spain</td>
<td>0.8</td>
<td>38.174</td>
<td>9.711</td>
<td>74.56%</td>
</tr>
<tr>
<td>Sweden</td>
<td>0.8</td>
<td>25.118</td>
<td>23.106</td>
<td>8.01%</td>
</tr>
<tr>
<td>Switzerland</td>
<td>0.8</td>
<td>7.228</td>
<td>4.733</td>
<td>34.52%</td>
</tr>
<tr>
<td>U.K.</td>
<td>0.8</td>
<td>17.076</td>
<td>3.379</td>
<td>80.21%</td>
</tr>
<tr>
<td>U.S.</td>
<td>0.8</td>
<td>29.868</td>
<td>5.207</td>
<td>82.57%</td>
</tr>
</tbody>
</table>

Note: The estimates of the measures are median biased corrected, using the median of the empirical distribution generated by the bootstrap procedure.

Table 3.1: Value of Loss and Performance Change
How important are these macroeconomic performance improvements? We evaluate this by calculating how much of the performance improvement translates into lower average inflation. That is, we find the inflation that would have had to take place in the second period (as a deviation from 2%), holding output variation equal to its first period level, in order to explain the performance changes. Put slightly differently, using equation (72), we control for the variance of output and attribute the changes in performance between the two periods only to changes in the average inflation rate (i.e., how close is average inflation to the target level of 2%).\(^{36}\) Looking at Israel, the 99.6% performance gain is equivalent to a drop of 179 percentage points in the average annual inflation rate from one period to the next. This is larger than the actual decrease in Israel’s annual inflation rate of nearly 120 percentage points between the 1980s and the 1990s. In the case of Australia, the 93.4% improvement is equivalent to a drop of 4.8 percentage points in the inflation rate, somewhat less than the over 5.9 percentage-point decline experienced there. Finally, for Mexico, the 93.0% improvement corresponds to a 65 percentage-point drop in inflation, slightly higher than the fall from nearly 70% to 20% that actually occurred. Overall, we conclude that large percentage changes in performance signal sizeable macroeconomic improvements.

\(^{36}\) The computation of the inflation change that can account for the performance change come from setting \(\Delta P\) equal to \(P_1 - [\lambda(\Delta \pi - 0.02)^2 + (1 - \lambda)Var(y_1)]\).

85
3.4.2 More Efficient Policy or a Calmer World?

Finally, we have arrived at the primary purpose for deriving all of these measurements: dividing the performance change $\Delta P$ into the portion that is accounted for by improved policy efficiency, $\Delta E$, and the portion due to changes in the variability of supply shocks, $\Delta S$. Given these other measures, we can compute the proportion of performance change that is due to a change in the efficiency of policy, $Q$. We report each of these for all of the countries in our sample. Importantly, in 21 of the 24 countries we study, policy efficiency improved from the 1980s to the 1990s.
### Table 3.2: Estimates of the Measures

Table 3.2 reports the (bias-corrected) estimates of $\Delta P$, $\Delta E$, $Q$, together with the probability that the estimated measures are of the opposite sign.\(^{37}\)

Out of the 21 countries that experienced a macro performance gain, 15 coun-

---

\(^{37}\)These probabilities are constructed as follows: If the estimate for the measure is greater than zero, we report the proportion of replications for which the measure is less than zero, divided by one thousand, and conversely for the case when the estimate is less than zero.
tries (Australia, Belgium, Chile, Denmark, France, Greece, Israel, Italy, Mexico, New Zealand, Portugal, Spain the UK and the US) experienced both an improvement in macro performance ($\Delta P > 0$) and a reduction in the variance of supply shocks ($\Delta S < 0$). Under these circumstances, $Q$ measures the contribution of a more efficient monetary policy to the improvement of macroeconomic performance. With the exception of Switzerland, all of the estimates suggest that policy has improved, and this improvement is significantly greater than zero at the 10% level for all of these countries.

Looking at the final column, the results show that more efficient policy accounted for between 84% (U.K.) and 99% (Italy) of the improvement in overall macroeconomic performance. Six other countries (Canada, Ireland, Japan, Korea, Netherlands and Sweden) experienced both a performance gain ($\Delta P > 0$) and an increase in the variability of supply shocks ($\Delta S > 0$). For these countries, the policy efficiency gain has more than offset the higher variability of aggregate shocks and, hence, monetary policy improvements account completely for the observed macro performance gain. More efficient policy is significant at the 10% level for Canada, Ireland and the Netherlands, but not for Japan, Korea and Sweden. Finally, we also observe that, in all countries that experienced a macro performance improvement (once again, excluding Switzerland), better monetary policy accounts for over 80 percent of the observed performance gain, suggesting that monetary policy has played a far more important role than the reduced variability of shocks in
macroeconomic stabilization. This can be clearly seen in Figure 3.3, which depicts the percentage gain in macro performance and the amount of this gain that is due to more efficient policy. We note that in the majority of the countries we study, the decrease in the variance of aggregate shocks has been insignificant.

![Figure 3.3: Changes in Performance due to Policy](image)

We now turn to the results for the countries that exhibited a macroeconomic performance loss from the 1980s to the 1990s ($\Delta P < 0$), which are only Austria, Finland and Germany. In all cases, our results suggest that the countries were exposed to a higher variance of supply shocks ($\Delta S > 0$). In particular, for the case of Finland more efficient policy was able to partially offset the increased variability of the shocks ($\Delta E > 0$), which implies that
the macroeconomic performance loss would have been much larger if not for policy improvement. Nevertheless, neither the performance change, nor the policy efficiency change are significantly different from zero for these three countries, and the performance losses in all cases were quite modest; in no case did it exceed a loss equivalent to an increase of 0.5\% in the average inflation rate.

Once again, we can look at examples to see how much improved policy translates into lower average inflation, controlling for the variances around the mean of both inflation and output. For Israel, the efficiency gain amounts to a decrease of 173 percentage points in the average annual inflation rate from one period to the next; for Australia, policy improvement corresponds to a drop of 4.5 percentage points in the inflation rate, while for Mexico it corresponds to a 61.3 percentage-point drop in average inflation.
<table>
<thead>
<tr>
<th>Country</th>
<th>Macroeconomic Performance Gain (in %)</th>
<th>Contribution of policy to change in performance (Q=ΔE/ΔP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>[93.3%, 93.5%]</td>
<td>[0.945, 0.949]</td>
</tr>
<tr>
<td>Austria</td>
<td>[-70.5%, 17.7%]</td>
<td>[-0.747, 1.040]</td>
</tr>
<tr>
<td>Belgium</td>
<td>[49.5%, 86.4%]</td>
<td>[0.812, 0.992]</td>
</tr>
<tr>
<td>Canada</td>
<td>[43.9%, 60.6%]</td>
<td>[1.424, 1.763]</td>
</tr>
<tr>
<td>Chile</td>
<td>[52.4%, 58.8%]</td>
<td>[0.895, 0.912]</td>
</tr>
<tr>
<td>Denmark</td>
<td>[54.9%, 90.7%]</td>
<td>[0.894, 0.977]</td>
</tr>
<tr>
<td>Finland</td>
<td>[-119%, 69.0%]</td>
<td>[-0.488, 36.807]</td>
</tr>
<tr>
<td>France</td>
<td>[69.3%, 92.7%]</td>
<td>[0.907, 1.014]</td>
</tr>
<tr>
<td>Germany</td>
<td>[-46.8%, -3.9%]</td>
<td>[-2.231, -0.704]</td>
</tr>
<tr>
<td>Greece</td>
<td>[61.1%, 61.5%]</td>
<td>[0.892, 0.949]</td>
</tr>
<tr>
<td>Ireland</td>
<td>[41.2%, 86.0%]</td>
<td>[0.994, 2.673]</td>
</tr>
<tr>
<td>Israel</td>
<td>[99.4%, 99.7%]</td>
<td>[0.963, 0.966]</td>
</tr>
<tr>
<td>Italy</td>
<td>[60.7%, 84.7%]</td>
<td>[0.963, 0.997]</td>
</tr>
<tr>
<td>Japan</td>
<td>[2.7%, 25.7%]</td>
<td>[1.087, 2.765]</td>
</tr>
<tr>
<td>Korea</td>
<td>[-6.0%, 41.6%]</td>
<td>[-0.342, 3.314]</td>
</tr>
<tr>
<td>Mexico</td>
<td>[91.9%, 93.4%]</td>
<td>[0.941, 0.943]</td>
</tr>
<tr>
<td>Netherlands</td>
<td>[42.7%, 68.0%]</td>
<td>[1.217, 1.513]</td>
</tr>
<tr>
<td>New Zealand</td>
<td>[73.4%, 95.6%]</td>
<td>[0.883, 0.911]</td>
</tr>
<tr>
<td>Portugal</td>
<td>[84.5%, 90.7%]</td>
<td>[0.868, 0.873]</td>
</tr>
<tr>
<td>Spain</td>
<td>[64.6%, 82.1%]</td>
<td>[0.893, 0.920]</td>
</tr>
<tr>
<td>Sweden</td>
<td>[-53.8%, 54.6%]</td>
<td>[0.297, 45.013]</td>
</tr>
<tr>
<td>Switzerland</td>
<td>[3.8%, 47.6%]</td>
<td>[-9.652, 0.196]</td>
</tr>
<tr>
<td>U.K.</td>
<td>[80.1%, 80.3%]</td>
<td>[0.834, 0.835]</td>
</tr>
<tr>
<td>U.S.</td>
<td>[70.9%, 91.1%]</td>
<td>[0.880, 0.969]</td>
</tr>
</tbody>
</table>

Note: The estimates of the measures are median biased corrected, using the median of the empirical distribution generated by the bootstrap procedure.

Table 3.3: Performance and Efficiency Changes over a range of values for inflation aversion

Finally, as a robustness check, we examine how the estimates of changes in performance and policy efficiency change as we vary λ. For the countries for which we set our baseline estimates λ equal to 0.8, we consider a range of 0.65 to 0.95. while for the four high inflation countries, where the baseline value of λ was set to 0.3, we consider a range between 0.15 and 0.45 for λ, consistent with the procedure followed in Chapter 2. This will allow us to
perform a comparative analysis of the measures in Chapter 4. Results are reported in Table 3.3.

Contemplating these ranges for the central bank's preferences, we see that our conclusions are largely unaffected. The only exceptions are Austria, Finland, Korea and Switzerland. In these four cases, changing $\lambda$ can cause a change in the sign for both $\Delta P$ and $Q$. 
3.5 Accounting for changes in performance and policy efficiency

What is responsible for the very pronounced improvements in policy that we have been able to document? Over the past 20 years, much has changed in the 24 countries that we study. Both private and official sector institutions have changed, and dramatically so in some cases. A prime candidate among possible explanations is the institutional framework of central banks. It is natural to ask if the move to more independent and transparent central banks could be responsible for the improvements that we have found.

Addressing this question head on is hampered by data availability. We have no consistent data on changes in independence, transparency and accountability of central banks – those things that theory tell us should matter for the ability of monetary policymakers to do their jobs. Cecchetti and Krause (2002) do look at the relationship between a set of 1998 survey measures of these framework variables and macroeconomic performance and policy efficiency during the 1990s. They find that, with the exception of a combination of transparency and credibility, these end-of-period measures cannot explain the changes over the prior two decades.\footnote{Cecchetti and Krause (2002) measure policy credibility by looking at past inflation performance.}

It is interesting to go further in assessing the role of central bank independence in explaining the cross-differences in the changes in macroeconomic
and policy outcomes. To do this, we construct three measures of the change in independence based on measures from the 1980s. Specifically, we standardize Fry et al.'s (2000) index for independence, which takes a base year 1998, and compare it to the standardized indices from the studies by Alesina (1988), Grilli, Masciandaro and Tabellini (1991) and Cukierman and Lippi (1999) (all of these are only available for a subset of the countries we study); for this last study we use the 1990 data for the independence index. In this way, we obtain three different measures of changes in central bank autonomy and relate them to our measures of performance and policy efficiency.

<table>
<thead>
<tr>
<th>No. of countries</th>
<th>Macro Performance Change</th>
<th>Policy Efficiency Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alesina, 1988</td>
<td>0.329</td>
<td>0.430</td>
</tr>
<tr>
<td></td>
<td>(0.23)</td>
<td>(0.11)</td>
</tr>
<tr>
<td>Grilli et. al., 1991</td>
<td>0.173</td>
<td>0.258</td>
</tr>
<tr>
<td></td>
<td>(0.49)</td>
<td>(0.30)</td>
</tr>
<tr>
<td>Cukierman and Lippi, 1999</td>
<td>-0.005</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td>(0.99)</td>
<td>(0.92)</td>
</tr>
</tbody>
</table>

*P-values are in parenthesis*

**Table 3.4: Performance, Efficiency and CB Independence (Correlation coefficients)**

Table 3.4 presents simple correlations between the three indices of independence changes and our measures of macroeconomic performance and policy efficiency changes. We observe that there is a positive correlation between changes in central bank autonomy and the performance and efficiency loss measures.
Unfortunately, none of these correlations is significantly different from zero at even the 10% level.\(^{39}\)

This result, in conjunction with the findings in Cecchetti and Krause (2002), suggests that factors other than the monetary policy framework may account for the cross-country differences in macroeconomic outcomes and policy efficiency. Cecchetti and Krause (2001) explore the possibility that changes in the financial structure may be responsible. They note that a reduction in direct state ownership of bank assets and the introduction of explicit deposit insurance can help explain improvements in measures like \(\Delta P\) and \(\Delta E\). This is consistent with the lending view of the monetary transmission process, which posits that financial institutions—and their importance as a source of funds for private agents—play a key role in determining the impact policy will have on its goal variables.

Still, in order to determine why countries vary so much in their improvements in performance and policy, we would need to go into more detail by analyzing the events that took place in each country individually during the period under consideration. Such an endeavor is beyond the scope of this study.

\(^{39}\)Another factor that may explain changes in performance and efficiency, as we mentioned in Section 2, is a shift towards inflation targeting. Looking at the 24 countries, we find evidence pointing to a positive correlation between adopting inflation targeting and better macroeconomic and policy outcomes. This result, however, is mostly due to improvements experienced by three countries (Israel, Mexico and Chile), which adopted inflation targeting in the 1990s, as a reaction of the high inflation they had during the 1980s. Controlling for these three cases, the correlation becomes no longer significant.
3.6 Conclusion

This chapter proposes a general methodology for analyzing changes in macroeconomic performance and identifying the relative contributions of improvements in the efficiency of monetary policy and changes in the variability of aggregate supply shocks. We apply our technique to a cross-section of 24 industrialized and developing countries in order to compare their macroeconomic performance in the 1980s with that in the 1990s. We are able to determine that in 21 of the 24 countries that we study, monetary policy became more efficient in the 1990s.

In 20 of the 21 countries that experienced more stable macroeconomic outcomes, better policy accounted for over 80% of the measured gain. While policy efficiency improved in Finland, it was unable to completely offset the increased variance of shocks hitting the economy. Only in Austria and Germany did both policy deteriorate and the variance of supply shocks increase.

Finally, we consider some factors that may help in explaining the cross-country differences in macroeconomic and policy outcomes. Our findings, both in the present chapter and in previous research, suggest that elements such as central bank credibility and transparency, together with the nature of the financial system, can account for at least some portion of the observed improvements.
In summary, our results suggest that more efficient policy has been the driving force behind improved macroeconomic performance. At the same time it has also contributed, at least in part, to offsetting an increased variability of supply shocks in some countries. Overall, lower variability of the aggregate supply shocks has usually played a minor role.
CHAPTER 4

COMPARISON ACROSS MEASURES

The objective of this chapter is to compare the measures of monetary policy efficiency and performance gain presented in Chapters 2 and 3. We discuss the advantages and shortcomings of each of the measures, both in terms of their methodologies of estimation and implication and their usefulness and application to similar projects.

The three main criteria we shall use for evaluating the measures of efficiency are:

1. Theoretical features and ability to explain performance changes.

2. Computational tractability.

3. Robustness to changes in the assumptions made in the model and estimations.

The comparison across measures of monetary policy efficient is essential, since we are not only concerned in accounting for the increased macroeconomic stability in the past years, but, more importantly, we are interested
in providing policymakers with a useful tool for the purpose of evaluating policy efficiency (and the changes thereof) in the present and future. To save notation, we shall hereafter refer to the approach described in Chapter 2 as the “policy rule method” while the one used in Chapter 3 will be named the “efficiency frontier method”.

From a theoretical perspective, the policy rule approach directly identifies aggregate supply and demand shocks, whereas the efficiency frontier method only does so indirectly. For the estimation of the frontier we use an instrument rule which depends on the observable variables of the economy (namely inflation, output and lagged interest rates)\(^{40}\), which is the approach that is followed in practice by central banks, while in the policy rule approach the instrument is modeled as a response to the observed shocks. If the shocks were perfectly observable, the policy rule method would be the preferred one, since one can directly establish which is the optimal rule to be followed; however, if the shocks are not perfectly observed, then an estimation error may lead to a greater misspecification of the rule and, therefore, the use of the efficiency frontier method would be more desirable.

In terms of computational tractability, the efficiency frontier approach requires estimating the frontier through a numerical approximation, as a result of a nonlinear optimization. This yields an additional advantage of the policy rule method, which only requires to estimate the relevant parameters.

\(^{40}\)See Fuhrer (1997).
without having to proceed with an optimization program. Nevertheless, with the increasing capacity of computer processors this hardly becomes an issue.

Finally, we take a brief look at the results themselves. Comparing the two approaches we find that the results are very similar in nature, since they tend to suggest both a significant improvement in macroeconomic outcomes and a key role of monetary policy in the reduction of inflation and output fluctuations. Two important differences between the results obtained through the alternative approaches do arise, and we consider them important for the robustness properties of the measures. First, the efficiency frontier method estimates of performance gain are in general slightly smaller than the ones derived from the policy rule method. This can be due to the fact that performance using the former approach employs a Hodrick-Prescott filter to obtain the target level for output, which yields a lower output growth variability than the one obtained if we consider a log-linear trend, as is the case with the policy rule approach. Still, the differences are only slight in most of the cases. A second and perhaps more important aspect is that the estimates of monetary policy contribution to stabilization according to the efficiency frontier method are most of the times higher (and in some cases substantially so) than the ones resulting from the policy rule approach. This may be a result of either an underestimation of the variability of supply and demand shocks under the efficiency frontier method, or that the magnitude of these shocks is overestimated through its direct identification using the policy rule.
Overall, there is no straightforward answer as to which method will be preferred; nevertheless, this discussion may not be that crucial, given that we observe very similar results using both approaches.
CONCLUSION

As discussed in the introduction, the main objective of this research is to develop a theoretical framework within which to study this observed general improvement in macroeconomic performance. In particular we concentrate on the role of monetary policy, asking whether improved policymaking by central bankers can account for the lower observed inflation and output growth fluctuations, or inflation and output variability. The evidence suggests that in a broad cross-section of countries inflation volatility has fallen markedly while output variability has either fallen or risen only slightly. We attribute this increased stability to two possible factors: 1) more efficient policy-making by the monetary authority, and 2) a reduction in the variability of the aggregate supply shocks.

The discussion in Chapter 1 provides a rationale for an active role of monetary policy in stabilization. The equilibrium model gives a theoretical justification for the inflexibility of prices to move upward or downward, as a result of firms' inability to perfectly observe demand and supply shocks. This price stickiness arises solely as a consequence of uncertainty, and it does not require either prices or wages to be predetermined. The two main implications of this result are that the monetary authority can have real effects on the economy and, more importantly, that policymakers can indeed
help reduce inflation and output fluctuations, should it be the case that the central bank has more information about the nature and size of the shocks than private agents.

Chapters 2 and 3 focus on the empirical question of establishing the degree in which monetary policy has contributed towards stabilizing inflation and output volatility in a number of countries. We develop two different methods for measuring changes in performance, and allocate the source of performance changes to these two factors. One first technique involves estimating an optimal policy rule and evaluating how close central banks operate to this rule. A second technique involves estimating movements toward an inflation and output variability efficiency frontier, and shifts in the frontier itself. Using both methods, we study the change from the 1980s to the 1990s in the macroeconomic performance of 24 countries and find that, for most of the analyzed countries, more efficient policy has been the driving force behind improved macroeconomic outcomes.

Finally, in Chapter 4 we compare the measures of monetary policy efficiency and performance gain presented in Chapters 2 and 3. We discuss the advantages and shortcomings of each of the measures, both in terms of their methodologies of estimation and implication and their usefulness and application to similar projects. While the empirical results are robust to choosing either of these two techniques, one possesses the advantage of being theoretically more palatable, while the other one is more consistent with the
way central banks operate. These results justify further inquiry into how central banks can effectively stabilize inflation and output growth.
APPENDICES

Appendix A to Chapter 1: Derivation of the Optimal Policy Rule Parameters

In order to derive the parameters $a^*$ and $b^*$ of the optimal policy rule, let us substitute the expressions for the deviations of output and inflation from their respective target levels (equations (30) and (31)) into the loss function (equation (32)), i.e.:

$$L = (1 + \omega \gamma)^{-2} \{ \lambda [-\phi\gamma (\bar{r} - d) - s]^2 + (1 - \lambda) [-\phi (\bar{r} - d) + \omega s]^2 \}.$$  \hspace{1cm} (A1)

Minimizing (A1) with respect to the policy instrument, $\bar{r}$, yields the following first-order condition:

$$2\lambda\phi\gamma[-\phi\gamma (\bar{r} - d) - s] + 2(1 - \lambda)\phi[-\phi (\bar{r} - d) + \omega s] = 0.$$  \hspace{1cm} (A2)

Simplifying the expression and arranging terms:

$$\phi[\lambda\gamma^2 + (1 - \lambda)]\bar{r} = \phi[\lambda\gamma^2 + (1 - \lambda)]d + (-\lambda\gamma + (1 - \lambda)\omega)s.$$  \hspace{1cm} (A3)

Solving for the optimal policy rule $\bar{r}^*$ in terms of the aggregate demand and aggregate supply shocks yields equation (33), with the parameters $a^*$ and $b^*$ given by:

$$a^* = 1,$$  \hspace{1cm} (A4)

$$b^* = \frac{-\lambda\gamma + (1 - \lambda)\omega}{\phi[\lambda\gamma^2 + (1 - \lambda)]}.$$  \hspace{1cm} (A5)
Appendix B to Chapter 2: Estimates of Structural Parameters

Estimating the model (65)-(66) for the periods 1983:I-1990:IV and 1991:I-1998:IV for the 24 countries of our sample yields the parameters $\omega$, $\gamma$ and $\phi$ for each period, which we present in Table B.1.

<table>
<thead>
<tr>
<th>Country / Period</th>
<th>$\omega$</th>
<th>$\gamma$</th>
<th>$\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>1</td>
<td>0.8347</td>
<td>1.1163</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.1613</td>
<td>1.1537</td>
</tr>
<tr>
<td>Austria</td>
<td>1</td>
<td>0.7549</td>
<td>0.3976</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.9016</td>
<td>0.5236</td>
</tr>
<tr>
<td>Belgium</td>
<td>1</td>
<td>1.3584</td>
<td>1.1136</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.5804</td>
<td>1.1424</td>
</tr>
<tr>
<td>Canada</td>
<td>1</td>
<td>1.4229</td>
<td>0.5557</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>1.1126</td>
<td>1.2422</td>
</tr>
<tr>
<td>Chile</td>
<td>1</td>
<td>1.3962</td>
<td>0.5268</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>0.5615</td>
<td>2.1549</td>
</tr>
<tr>
<td>Denmark</td>
<td>1</td>
<td>1.4167</td>
<td>0.6789</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.2543</td>
<td>0.4502</td>
</tr>
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<td>1.4095</td>
<td>0.2997</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.3122</td>
<td>0.6755</td>
</tr>
<tr>
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</tr>
<tr>
<td></td>
<td>2</td>
<td>0.8932</td>
<td>1.0384</td>
</tr>
<tr>
<td>Germany</td>
<td>1</td>
<td>1.8958</td>
<td>0.6403</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.9628</td>
<td>0.3131</td>
</tr>
<tr>
<td>Greece</td>
<td>1</td>
<td>1.1835</td>
<td>0.8792</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2.1953</td>
<td>1.5162</td>
</tr>
<tr>
<td>Ireland</td>
<td>1</td>
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</tr>
<tr>
<td></td>
<td>2</td>
<td>0.9758</td>
<td>0.3702</td>
</tr>
<tr>
<td>Israel</td>
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<td>1.8254</td>
<td>4.8984</td>
</tr>
<tr>
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<td>1.4805</td>
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</tr>
<tr>
<td></td>
<td>2</td>
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<td></td>
<td>2</td>
<td>2.7327</td>
<td>0.3385</td>
</tr>
</tbody>
</table>

Table B.1: Estimates of the Structural Parameters

(continued onto next page)
<table>
<thead>
<tr>
<th>Country / Period</th>
<th>$\omega$</th>
<th>$\gamma$</th>
<th>$\phi$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korea</td>
<td></td>
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<td></td>
</tr>
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<td>1.5956</td>
<td>0.3428</td>
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</tr>
<tr>
<td>2</td>
<td>3.4752</td>
<td>0.2258</td>
<td>1.6740</td>
</tr>
<tr>
<td>Mexico</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
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<td>0.5525</td>
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<td>1.1899</td>
<td>0.4593</td>
<td>0.5618</td>
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<tr>
<td>Netherlands</td>
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<td></td>
</tr>
<tr>
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<td>0.6431</td>
<td>0.3384</td>
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</tr>
<tr>
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<td>2.1246</td>
<td>0.1632</td>
<td>2.1008</td>
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<tr>
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<td>0.4821</td>
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<tr>
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</tr>
<tr>
<td>1</td>
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<td>2</td>
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<td>Spain</td>
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<td>2</td>
<td>1.6842</td>
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<tr>
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<td>0.9780</td>
<td>1.5009</td>
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<td>2</td>
<td>0.7915</td>
<td>3.3571</td>
<td>0.9216</td>
</tr>
</tbody>
</table>

*Table B.1: Estimates of the Structural Parameters*
Appendix C to Chapter 3: Model Specification

The basic model consists of two equations. The aggregate demand equation (77) relates (demeaned and detrended) log industrial production to two of its own lags, two lags of the nominal interest rate, one lag of demeaned inflation and one lag of demeaned external price inflation. The aggregate supply equation (78) relates inflation to three of its own lags, one lag of (demeaned and detrended) log industrial production and one lag of demeaned external price inflation. For some countries we also included additional lags, and dummy variables to account for currency crises, sharp recessions, or structural changes. Table C.1 provides a description of all the variables included in the aggregate demand - aggregate supply model for each country.
<table>
<thead>
<tr>
<th>Country</th>
<th>Explanatory variables in AD-equation (# of lags)</th>
<th>Explanatory variables in AS-equation (# of lags)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
<td>Austria</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
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<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (2), Dummy variable (exchange rate crisis 93-I-IV)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (exchange rate crisis 93-I-IV)</td>
</tr>
<tr>
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<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
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<td>Chile</td>
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<td>Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (in increase in money growth 92-I)</td>
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<td>Denmark</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (sharp output decline 86-I-87-I)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
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<td>Finland</td>
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<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
<td>France</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
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<td>Germany</td>
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<td>Greece</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (exchange rate crisis 93-I-IV and 93-I-IV)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
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<td>Ireland</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
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<td>Israel</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
<td>Italy</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
<td>Japan</td>
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<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
<td>Korea</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
<td>Mexico</td>
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<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
<td>Netherlands</td>
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<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
<td>New Zealand</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
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<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
<td>Spain</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
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<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
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<tr>
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<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
<td>UK</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
<tr>
<td>USA</td>
<td>Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)</td>
<td>Industrial production (2), Inflation (2), External Inflation (1)</td>
</tr>
</tbody>
</table>

**Table C.1: Model Specification**
Appendix D: Data Sources

Inflation and Output data for Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden and the United Kingdom are from Datastream; those for Australia, Canada, Japan, Mexico, New Zealand, Switzerland and the United States are taken from the OECD Main Economic Indicators. Data for Chile are from the Central Bank of Chile's WWW-homepage (inflation), and from DRI (industrial production); Israeli data are taken from DRI (industrial production, and inflation). Korea's data are taken from IFS (industrial production) and DRI (inflation).
BIBLIOGRAPHY


of the Monetary Policy in the Countries of the Euro Area”, mimeo prepared for European Central Bank’s Monetary Transmission Network.


