

# Has Monetary Policy Become More Efficient? A Cross-Country Analysis

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## Abstract

Over the past twenty years, macroeconomic performance has improved in industrialized and developing countries alike. In a broad cross-section of countries inflation volatility has fallen markedly while output variability has either fallen or risen only slightly. This increased stability can be attributed to either: 1) more efficient policy-making by the monetary authority, 2) a reduction in the variability of the aggregate supply shocks, or 3) changes in the structure of the economy. In this paper we develop a method for measuring changes in performance, and allocate the source of performance changes to these two factors. Our technique involves estimating movements toward an inflation and output variability *efficiency frontier*, and shifts in the frontier itself. 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 performance.

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# 1 Introduction

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 a decade ago. Looking at a sample of 24 countries comparing the 1980s and the 1990s, we see that 20 experienced lower inflation variability, while output volatility was lower in 15.

There are a number of candidate explanations for this widespread improvement in macroeconomic outcomes. One possibility is that the world has become a more stable place. If there are no shocks hitting an economy, it will surely be more stable. Alternatively, monetary policymakers may have become more skillful at implementing policies to meet their stabilization objectives. That is, the monetary policies of the 1990s may have been more efficient than those of the 1980s.

The purpose of this paper is to develop a method for measuring the contribution of improved monetary policy to observed changes in macroeconomic performance and then 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 – and some 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 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 attributed to changes in the volatility of supply shocks and the structure of the economy, while movements toward the frontier measure improvements in policy efficiency. Thus, our calculations allow us to parse improvements in macroeconomic performance into the portion that can be accounted for by more efficient policy and the part that can be attributed to lower supply shock variability and changes in the structure of the economy.

Throughout the paper, 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 view, improved efficiency reflects 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 stabi-

lize the economy will depend on the financial structure in that country. Furthermore, changes in independence, credibility and transparency of policy can affect the ability of policymakers to perform effectively.

Finally, there are a myriad of fiscal, trade and labor market policies that affect macroeconomic structure and so will have an impact both on the location of the efficiency frontier and on monetary policy effectiveness. For instance, changes in the degree of nominal rigidity or inflation expectations may affect the shape and location of the efficiency frontier via changes in the structure of the economy. Also, *improvements in the management of final goods inventories* may reduce the effects of supply disturbances to the economy (Kahn, McConnell and Pérez-Quirós, 2002), thus affecting the frontier. Therefore all these factors would show up as changes in the variability of aggregate supply shocks in our method, and thus our definition of variability of supply shocks necessarily includes some changes in the structure of the economy not captured by the slope of the efficiency frontier. While our technique is too coarse to distinguish among all of these possible causes of the changes that we document, we consider it a necessary first step.

The remainder of the paper is divided into six sections. In Section 2, we take a preliminary look at the data on macroeconomic outcomes for the 24 countries in our sample. Section 3 introduces the proposed method to analyze the changes in macroeconomic performance. Section 4 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 5 presents and discusses the main results. Our results suggest that improved monetary policy has played a stabilizing role in 21 of the 24 countries. Seventeen countries experienced reduced supply shock variability, but overall this had a modest impact on performance. Importantly, we find that our results are robust to alternative assumptions regarding the preferences and targets of the monetary authority. Section 6 discusses some explanations for the cross-country differences in the changes in macroeconomic performance and policy efficiency, while Section 7 concludes the paper.

## 2 Empirical Facts

We study a sample of 24 countries, ranging from large industrial countries to small developing ones.<sup>1</sup> 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, using quarterly data. 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.

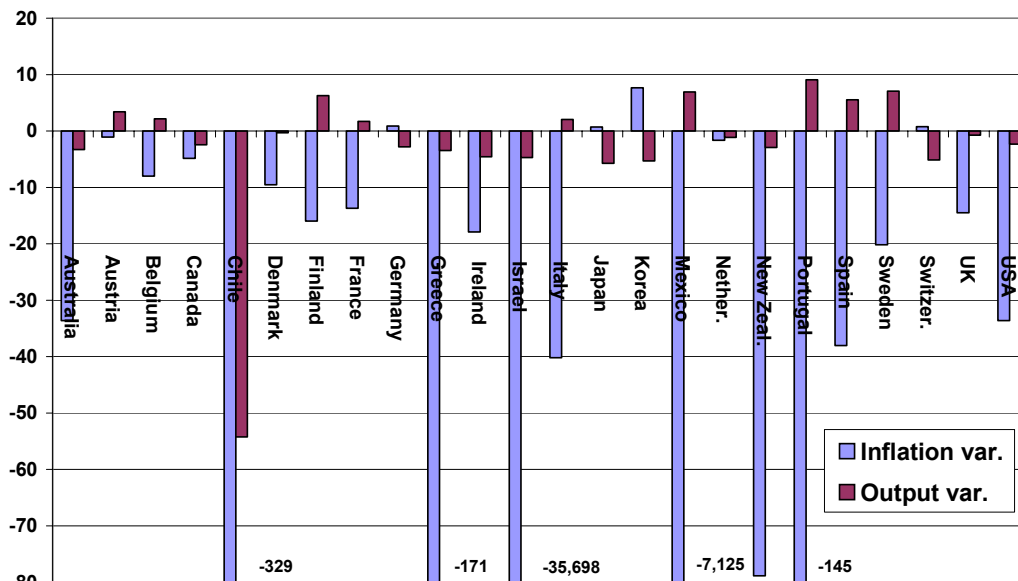
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<sup>1</sup>The list includes Australia, Austria, Belgium, Canada, Chile, Denmark, Finland, France, Germany, Greece, Ireland, Israel, Italy, Japan, Korea, Mexico, Netherlands, New Zealand, Portugal, Spain, Switzerland, Sweden, the United Kingdom, and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

To measure inflation and output volatility, our baseline assumption is that policymakers are interested in achieving an inflation target of 2% and in minimizing the variability of output around its potential level.<sup>2</sup> We discuss these assumptions at length in Section 5, where we consider alternative targets in our empirical analysis.

Figure 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.<sup>3</sup> Finally, we note that seven out of the nine countries in which output variability rose 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.

**Figure 1: Change in inflation and output variability (83-90 vs. 91-98)**



Inflation variability is measured as the squared deviation from a 2% target level (x 10,000)

Output variability is measured as the squared deviation from an H-P trend (x 10,000)

We use the information in Figure 1 to construct measures of macroeconomic performance changes. In the next section, we describe how to obtain these measures and, furthermore,

<sup>2</sup>For each country, we measure potential output as Hodrick-Prescott filtered industrial production.

<sup>3</sup>See Fry, Julius, Mahadeva, Roger and Sterne (2000) for a discussion of the changes in central bank targeting procedures.

how to identify the sources of the performance changes.

### 3 Measuring the Sources of Macroeconomic Performance Changes

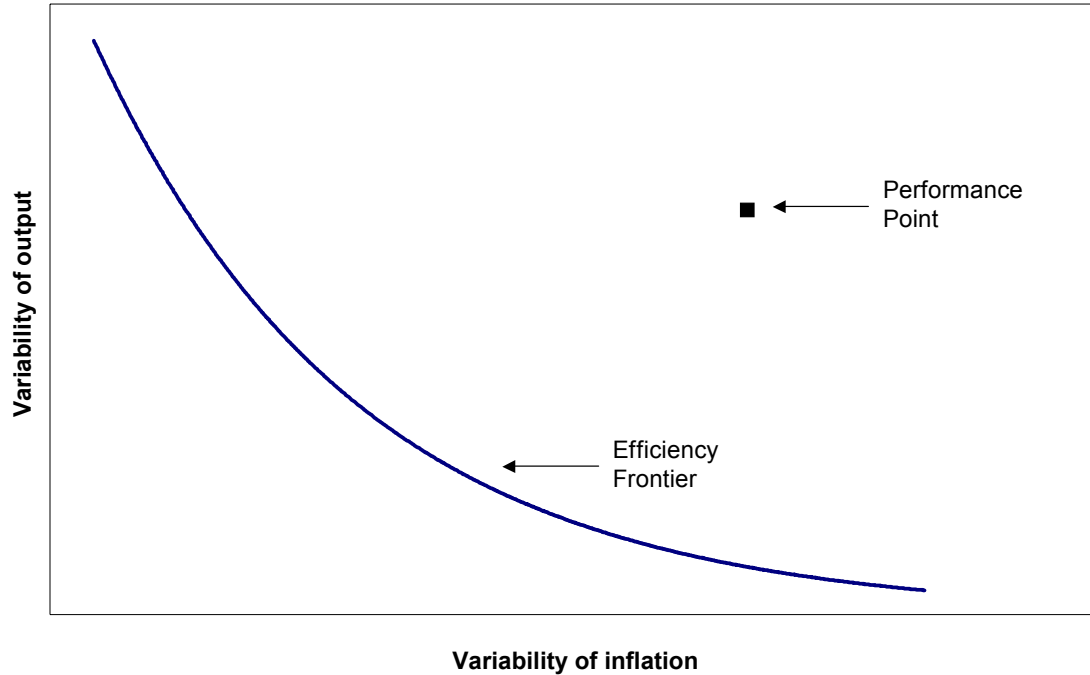
Our goal is to divide changes in macroeconomic performance into the portion that is due to changes in the variability of shocks and the part that can be ascribed to changes in policy efficiency. To do this, we rely on the use of the inflation-output variability trade-off, or efficiency frontier. As we explain, increases or decreases in the variability of supply shocks shift 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 4 contains analytical derivations that are based on a specific, and empirically tractable, macroeconomic model.

The concept of an inflation-output variability frontier is most easily 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.<sup>4</sup>

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<sup>4</sup>For a simple algebraic model and a discussion of the derivation of the output-inflation variability frontier see Cecchetti and Ehrmann (2001).

**Figure 2: Efficiency frontier and performance point**



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 2, 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; while the slope of the frontier is determined by the structure of the economy. 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 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. This is the standard quadratic loss function used in most contemporary analyses of central bank policy. We can summarize this loss as:<sup>5</sup>

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

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

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<sup>5</sup>We note that, in what follows,  $Var(\cdot)$  stands for variability with respect to a *target* of the variable in question, and it is not necessarily equal to variance around the mean.

an economy's performance, and changes in macroeconomic outcomes, using measures based on this loss. We note that we have not included a discount factor in the loss function, since our measures of performance and policy efficiency described below only consider comparing two periods of interest.

Obviously, computation of the loss requires a value of the preference parameter  $\lambda$ , which can be either estimated within our method or can be chosen based on plausible values obtained elsewhere.<sup>6</sup> Importantly, our results are robust to both approaches and also to a plausible *range* of values for  $\lambda$ . We defer discussion of how  $\lambda$  is chosen until Section 5.1. 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 variability of supply shocks that we will use in our empirical analysis. First, macroeconomic performance is simply a weighted average of the observed variability of output and inflation. We call this  $P_i$  ( $i = 1, 2$ ; periods), and define it as follows:

$$P_i = \lambda Var(\pi_i) + (1 - \lambda)Var(y_i). \quad (2)$$

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.<sup>7</sup> The alternative of allowing  $\lambda$  to vary across periods renders  $P_1$  and  $P_2$  incomparable, for example,  $\Delta P$  can indicate a decrease in macroeconomic performance even though *both* the variability of output and inflation fall.

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 variabilities of output and inflation. Since the efficiency frontier shifts 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:

$$S_i = \lambda Var(\pi_i)^* + (1 - \lambda)Var(y_i)^* \quad (3)$$

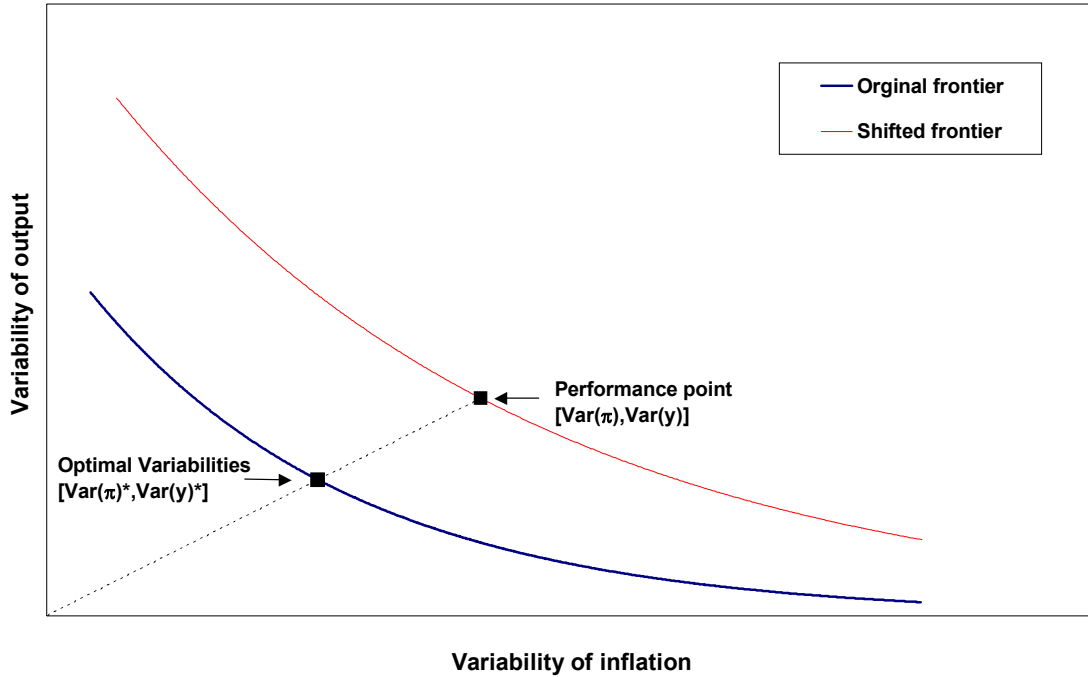
where  $Var(\pi_i)^*$  and  $Var(y_i)^*$  are the variabilities of inflation and output under optimal policy for period  $i$ , respectively.  $\Delta S = S_2 - S_1$  is the measure we use to quantify the change in the variability of supply shocks. We define  $\Delta S$  in this fashion, instead of the 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.

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<sup>6</sup>There is a growing literature trying to estimate the preferences of policymakers. See for instance Cecchetti and Ehrman (2001), Dennis (2001) and Favero and Rovelli (2003).

<sup>7</sup>We note, however, that our findings are robust to computing the measures using estimated preferences from the first *or* second period. These results are available upon request.

**Figure 3: Derivation of the Optimal Variabilities**



To determine  $Var(\pi_i)^*$  and  $Var(y_i)^*$  we use the following procedure. Beginning with Figure 2, we shift the efficiency trade-off homothetically outward until it passes through the performance point representing the observed variabilities of inflation and output. Figure 3 shows the original and shifted frontiers. We determine the optimal variabilities as the point on the original frontier associated with this same performance point. In Section 4 we describe the derivation of the optimal variability point analytically. A geometrical interpretation of the optimal variability point is the intersection point of the original frontier with a line from the origin to the performance point.

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:

$$E_i = \lambda[Var(\pi_i) - Var(\pi_i)^*] + (1 - \lambda)[Var(y_i) - Var(y_i)^*] \quad (4)$$

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 use 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:

$$Q = \frac{\Delta E}{|\Delta P|} \quad (5)$$

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 variability 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 estimating or choosing plausible values of the preference parameter  $\lambda$ , we are then able to compute  $\Delta P$ ,  $\Delta E$ , and  $Q$ . This is the task of the remainder of the paper.

## 4 Estimating the Efficiency Frontier

The efficiency frontier is constructed as follows. Beginning with the quadratic loss function representing trade-offs 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 variability 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 4.1, we estimate simple structural models of inflation and output for each of the 24 countries in our sample. Next, in Section 4.2, we undertake a number of diagnostic and specification checks to establish the adequacy of our empirical models. In Section 4.3, we describe the construction of the efficiency frontier from the model estimates. Finally, in Section 4.4, we describe a simulation-based approach to assess the reliability of the estimated measures.

### 4.1 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:

$$y_t = \sum_{l=1}^2 \alpha_{1l} i_{t-l} + \sum_{l=1}^2 \alpha_{1(l+2)} y_{t-l} + \sum_{l=1}^2 \alpha_{1(l+4)} \pi_{t-l} + \alpha_{17} x_{t-1} + \varepsilon_{1t} \quad (6)$$

$$\pi_t = \sum_{l=1}^2 \alpha_{2l} y_{t-l} + \sum_{l=1}^2 \alpha_{2(l+2)} \pi_{t-l} + \alpha_{25} x_{t-1} + \varepsilon_{2t} \quad (7)$$

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,  $x$ , to account for the inter-relation between the economy of interest and its main trading partner.<sup>8</sup> 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.<sup>9</sup> 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 (6) and (7) for each country separately in each subperiod with quarterly data, 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.

## 4.2 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 properties of our data, and then move on to a comparison of the restricted model to a more general one that encompasses it.

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<sup>8</sup>External price inflation is measured as the sum of the annualized devaluation rate and the inflation of the main trading partner. See Appendix I.

<sup>9</sup>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 (6) and (7) to obtain the efficiency frontier.

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.<sup>10</sup>

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 and detrended endogenous variables 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.

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.<sup>11</sup> This provides justification for the single-equation estimation of the model.

Another interesting exercise is to compare the estimated coefficients across subperiods using structural stability (Chow) tests. If evidence is found that the estimated coefficients differ across subperiods for a country, it is an indication that the structure of the economy has somehow changed and that the efficiency frontier that policymakers face is different. Our measures are designed to take this into account when evaluating monetary policy. Nevertheless, even if no structural change in the coefficients is found, our measures are still meaningful since in this case the frontier has changed little and thus policy will be credited for the change in macro performance. With this in mind, we find evidence (at the 10% level) of structural change across periods in either equations (6) or (7) for 16 countries, and among the remaining 8 countries, 3 of them show evidence of structural change at a 14% level. There is, therefore, evidence that for most of the countries the frontiers have changed substantially from the 1980s to the 1990s.

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,

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<sup>10</sup>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.

<sup>11</sup>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.

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 (7).

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.<sup>12</sup>

Beginning with the VAR comparison, we find that, with the exception of Australia and Switzerland, the restrictions implied in equation (7) 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.<sup>13</sup> Nevertheless, restricting the coefficients on the lagged interest rate to zero for these two countries actually yields more sensible IRFs of inflation. 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.<sup>14</sup> 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.<sup>15</sup> We regard this as evidence that our structural model is correctly specified relative to a VAR. However, since some countries still present prize-puzzles under our preferred specification, we also provide below results for a restricted sample that ignores these countries.

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 relatively 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.<sup>16</sup> Apart for only

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<sup>12</sup>The impulse response functions and the value of the statistics of all diagnostic tests are not presented here to save space, but they are available upon request from the authors.

<sup>13</sup>In fact, for 19 countries the p-value of both tests is above 0.10.

<sup>14</sup>These countries are Australia, Canada, Denmark, Germany, Korea, Netherlands, New Zealand, Spain, Switzerland and the U.S.

<sup>15</sup>A rise in inflation following an increase in the nominal interest rate is commonly referred to as the *price puzzle*.

<sup>16</sup>Among the 13 countries are Korea and Netherlands, for which the restrictions were rejected for the

4 countries where the VAR is favored, in the remaining 7 the evidence is mixed. In sum, according to the information criteria the restrictions implied by the structural model do not seem inadequate.

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 (6) and (7) to construct the efficiency frontier, which will be then used to compute the measures of interest.

We finish this section by pointing out that when interest lies on a single country, a more detailed econometric model can be used to estimate the structure of the economy needed to apply our method. For instance, Cecchetti, Flores-Lagunes and Krause (2001) perform a more detailed analysis for Mexico, in which additional variables that help improve the structural model are considered and structural change tests for unknown break point are employed to divide the sample, among other things. In this particular case of Mexico, it turns out that the results in the detailed analysis are very similar to the ones obtained below.<sup>17</sup>

### 4.3 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 (1), we write this as:

$$E[L] = E [\lambda(\pi_t - \pi^*)^2 + (1 - \lambda)(y_t - y^*)^2], \quad (8)$$

where  $\pi^*$  and  $y^*$  are the policymaker's targets for inflation and output, respectively. This loss function does not include the interest rate or the exchange rate, since we assume that the fundamental concern of a central bank is domestic macroeconomic performance as measured by output and price stability. We note that even though reducing the volatility in the interest rate is not considered explicitly as an argument in the loss function, the dynamic structure of the economy may imply that the optimal feedback rule presents interest rate persistence. The presence of a relatively high persistence in both output and inflation in equations (6) and (7) respectively, will normally imply a high persistence of the interest rate in the policy rule equation.<sup>18</sup>

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second period.

<sup>17</sup>Cecchetti, Flores-Lagunes and Krause (2001) consider the subperiods 1982:I-1988:IV and 1991:I-1997:IV, average output growth as output target, and targets for inflation of 3.58% and 2.70%, which correspond to the average inflation rate of the US for each period. Using a slightly different measure for the contribution of policy, we estimate it at 93% of the macro performance gain. As we report in section 5.2, our estimate of this contribution is 94.2%

<sup>18</sup>For instance, estimating the AD-AS model for the US in the 1st period yields the following:  $y_t = -0.06i_{t-1} - 0.19i_{t-2} + 0.85y_{t-1} + 0.06y_{t-2} - 0.20\pi_{t-1} + 0.06\pi_{t-2} + \varepsilon_{1t}$  and  $\pi_t = 0.45y_{t-1} - 0.49y_{t-2} + 1.16\pi_{t-1} - 0.22\pi_{t-2} + \varepsilon_{2t}$  while the estimated equation for the policy rule results is  $i_t = 0.74i_{t-1} + 0.19y_{t-1} +$

Our baseline assumption is that the inflation target for all countries is 2%, and that monetary authorities want to keep industrial production as close as possible to its potential level, computed by applying the H-P filter. We explore the robustness of our results to different targets of both inflation (using average inflation for each period and H-P filtered inflation) and output (using a log-linear trend).

For the purposes of exposition, it is useful to rewrite the basic structural model in (6)-(7) using its state-space representation,

$$Y_t = BY_{t-1} + ci_{t-1} + DX_{t-1} + v_t \quad (9)$$

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

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

The policymaker's problem is to choose a path for the interest rate,  $i_t$ , in order to minimize (8), subject to the constraints imposed by (9). The linear-quadratic nature of the problem ensures that the solution for the control, the interest rate, will be linear. We write this as:

$$i_t = \Gamma Y_t + \Psi \quad (10)$$

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.<sup>19</sup> Equation (10) represents an unrestricted monetary policy rule (See Rudebusch and Svensson, 1999).<sup>20</sup>

The control problem is solved by finding  $\Gamma$  such that:<sup>21</sup>

$$\Gamma = -(c' H c)^{-1} c' H B \quad (11)$$

and

$$H = \Lambda + (B + c\Gamma)' H (B + c\Gamma) \quad (12)$$

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

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0.16 $y_{t-2}$  + 0.72 $\pi_{t-1}$  + 0.14 $\pi_{t-2}$  +  $\varepsilon_{3t}$ . Similarly, for the 2nd period the estimates are  $y_t = 0.01i_{t-1} - 0.17i_{t-2} + 0.89y_{t-1} - 0.11y_{t-2} - 0.34\pi_{t-1} + 0.26\pi_{t-2} + \varepsilon_{1t}$ ,  $\pi_t = 0.23y_{t-1} - 0.30y_{t-2} + 1.23\pi_{t-1} - 0.39\pi_{t-2} + \varepsilon_{2t}$  and  $i_t = 0.80i_{t-1} + 0.35y_{t-1} - 0.17y_{t-2} + 1.31\pi_{t-1} - 0.29\pi_{t-2} + \varepsilon_{3t}$ .

<sup>19</sup>See Chow (1975), pp. 158-159.

<sup>20</sup>The estimated interest rate equations for the 24 countries are available upon request from the authors.

<sup>21</sup>For a technical exposition of this procedure see Chow (1975), pp. 156-160.

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 2.

Given this estimate of the efficiency frontier, as we explained in Section 3, we perform a homothetic shift of the frontier so that it passes through the data point given by the observed variabilities of inflation and output. This point will imply a certain ratio of the variabilities of inflation and output. We determine the optimal variabilities of inflation and output by the point on the original frontier associated with that same ratio.

We use the estimated efficiency frontier to obtain the measures of interest presented in Section 3.<sup>22</sup> These measures (to be reported in Section 5) are simply estimates and not the true values of the quantities of interest. For this reason, in the next section, we describe the method we use to evaluate their reliability as estimates of the true measures.

#### 4.4 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 (6) and (7) is correctly specified, and that the corresponding error terms are independent but not identically distributed (inid). These two assumptions are sufficient conditions to apply the parametric recursive bootstrap. In Section 4.2, 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 4.1).

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.<sup>23</sup>

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;<sup>24</sup> we note,

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<sup>22</sup>The estimated frontiers for the 24 countries in each subperiod are available from the authors upon request.

<sup>23</sup>For a detailed discussion of the procedure see Li and Maddala (1996).

<sup>24</sup>In general, a median corrected estimator is obtained with the following formula:

however, that the median corrections are small and in no case do they change the sign of the estimates, which provides additional support for our specification.<sup>25</sup> The replications are also used to compute the probability that the estimated measure is of the opposite sign. This probability represents how likely is that the measure is not estimated in the right direction.

## 5 Results

We examine our results in three 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. In the last subsection we provide two robustness checks by restricting our analysis to those countries that do not show price-puzzles and also by comparing our method to results available elsewhere for the US using different time periods.

### 5.1 Performance Changes

We estimate models and frontiers for 24 countries over two sample periods, 1983:I-1990:IV and 1991:I-1998:IV. As noted in Section 2, in order to measure inflation and output variability, our baseline assumption is 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 variability, 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 in each period and an H-P filtered series for inflation as targets instead of the 2% target.<sup>26,27</sup>

Before computing the measures introduced in Section 3, we require a value of the preference parameter  $\lambda$ . As noted in that section,  $\lambda$  can be either estimated within our method or chosen based on plausible values of  $\lambda$  obtained elsewhere. Our baseline results are obtained using the latter approach, considering 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 (2003). 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 also show

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$$\hat{\beta}_{MC} = 2\hat{\beta} - \hat{\beta}_{median}^*$$

where  $\hat{\beta}$  is the original estimator and  $\hat{\beta}_{median}^*$  is the median obtained from the empirical distribution yielded by the bootstrap.

<sup>25</sup>The sizes of the median corrections are available upon request from the authors.

<sup>26</sup>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.

<sup>27</sup>The estimates of the measures with alternative targets for inflation and output are available upon request from the authors.

that our results are robust to this choice by considering a *range* of possible values for  $\lambda$  and recomputing our measures. Finally, we also computed our measures based on values of  $\lambda$  for each country estimated within our method. The results of this exercise are largely identical to those presented here and are available upon request.

With this in mind, Table 1 reports the value chosen for the inflation variability aversion coefficients and the value of the loss function,  $P_i$ , 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 value 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.

Turning to the results, we see in Table 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%.<sup>28</sup>

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 variability equal to its first period level, in order to explain the performance changes. Put slightly differently, using equation (1), we control for the variability 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%).<sup>29</sup> 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.

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<sup>28</sup>Using H-P filtered inflation and log-linear trend for output as targets the results are qualitatively identical to our baseline estimates except that the performance gains for most of the countries are slightly smaller. This is due to the reduction on the variability of inflation resulting from applying the H-P filter. Using average inflation and log-linear trend for output as targets the results are nearly identical to our baseline estimates. The only exceptions are that Austria and Finland now show a modest gain in performance, while Korea shows a moderate performance loss.

<sup>29</sup>The computation of the inflation change that can account for the performance change come from setting  $\Delta P$  equal to  $P_1 - [\lambda(\Delta\pi - 0.02)^2 + (1 - \lambda)Var(y_1)]$ .

**Table 1: Value of Loss and Performance Change**

Country	Value for $\lambda$	1983:I-1990:IV: Value of Loss (10,000*P <sub>1</sub> )	1991:I-1998:IV: Value of Loss (10,000*P <sub>2</sub> )	Macroeconomic Performance Gain (in %)
Australia	0.8	32.780	2.175	<b>93.37%</b>
Austria	0.8	3.623	4.914	<b>-35.63%</b>
Belgium	0.8	9.149	3.012	<b>67.08%</b>
Canada	0.8	11.324	5.655	<b>50.06%</b>
Chile	<b>0.3</b>	553.370	246.248	<b>55.50%</b>
Denmark	0.8	11.382	3.325	<b>70.79%</b>
Finland	0.8	14.642	16.304	<b>-11.36%</b>
France	0.8	12.857	2.320	<b>81.95%</b>
Germany	0.8	4.164	4.726	<b>-13.50%</b>
Greece	<b>0.3</b>	93.360	36.196	<b>61.23%</b>
Ireland	0.8	19.665	7.161	<b>63.59%</b>
Israel	<b>0.3</b>	10768.85	43.60	<b>99.60%</b>
Italy	0.8	40.340	6.892	<b>82.92%</b>
Japan	0.8	11.264	8.804	<b>21.85%</b>
Korea	0.8	26.296	24.149	<b>8.89%</b>
Mexico	<b>0.3</b>	2288.62	160.035	<b>93.01%</b>
Netherlands	0.8	2.728	1.267	<b>53.55%</b>
New Zealand	0.8	73.419	10.588	<b>85.58%</b>
Portugal	0.8	218.901	25.981	<b>88.13%</b>
Spain	0.8	38.174	9.711	<b>74.56%</b>
Sweden	0.8	25.118	23.106	<b>8.01%</b>
Switzerland	0.8	7.228	4.733	<b>34.52%</b>
U.K.	0.8	17.076	3.379	<b>80.21%</b>
U.S.	0.8	29.868	5.207	<b>82.57%</b>

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

## 5.2 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 2: Estimates of the Measures**

<b>Country</b>	<b>Change in policy efficiency (10,000*<math>\Delta E</math>)</b>		<b>Change in macro performance (10,000*<math>\Delta P</math>)</b>		<b>Contribution of policy to change in performance (<math>Q=\Delta E/\Delta P</math>)</b>	
<b>Australia</b>	<b>28.98</b>	(0.00)	<b>30.60</b>	(0.00)	<b>0.947</b>	(0.00)
<b>Austria</b>	<b>-0.96</b>	(0.28)	<b>-1.29</b>	(0.21)	<b>-0.744</b>	(0.28)
<b>Belgium</b>	<b>5.41</b>	(0.10)	<b>6.14</b>	(0.06)	<b>0.882</b>	(0.10)
<b>Canada</b>	<b>9.14</b>	(0.00)	<b>5.67</b>	(0.00)	<b>1.612</b>	(0.00)
<b>Chile</b>	<b>277.55</b>	(0.00)	<b>307.12</b>	(0.00)	<b>0.904</b>	(0.00)
<b>Denmark</b>	<b>7.49</b>	(0.00)	<b>8.06</b>	(0.00)	<b>0.930</b>	(0.00)
<b>Finland</b>	<b>2.46</b>	(0.25)	<b>-1.66</b>	(0.32)	<b>1.481</b>	(0.25)
<b>France</b>	<b>9.99</b>	(0.00)	<b>10.54</b>	(0.00)	<b>0.948</b>	(0.00)
<b>Germany</b>	<b>-0.59</b>	(0.26)	<b>-0.56</b>	(0.26)	<b>-1.045</b>	(0.26)
<b>Greece</b>	<b>53.31</b>	(0.00)	<b>57.16</b>	(0.00)	<b>0.933</b>	(0.00)
<b>Ireland</b>	<b>12.91</b>	(0.00)	<b>12.50</b>	(0.29)	<b>1.033</b>	(0.00)
<b>Israel</b>	<b>10340</b>	(0.00)	<b>10725</b>	(0.00)	<b>0.964</b>	(0.00)
<b>Italy</b>	<b>33.15</b>	(0.00)	<b>33.45</b>	(0.00)	<b>0.991</b>	(0.00)
<b>Japan</b>	<b>2.76</b>	(0.24)	<b>2.46</b>	(0.27)	<b>1.123</b>	(0.24)
<b>Korea</b>	<b>2.88</b>	(0.44)	<b>2.15</b>	(0.46)	<b>1.344</b>	(0.44)
<b>Mexico</b>	<b>2005.6</b>	(0.00)	<b>2128.6</b>	(0.00)	<b>0.942</b>	(0.00)
<b>Netherlands</b>	<b>1.97</b>	(0.00)	<b>1.46</b>	(0.00)	<b>1.352</b>	(0.00)
<b>New Zealand</b>	<b>56.57</b>	(0.04)	<b>62.83</b>	(0.02)	<b>0.900</b>	(0.04)
<b>Portugal</b>	<b>168.02</b>	(0.00)	<b>192.92</b>	(0.00)	<b>0.871</b>	(0.00)
<b>Spain</b>	<b>25.91</b>	(0.00)	<b>28.46</b>	(0.00)	<b>0.910</b>	(0.00)
<b>Sweden</b>	<b>9.57</b>	(0.24)	<b>2.01</b>	(0.47)	<b>4.755</b>	(0.24)
<b>Switzerland</b>	<b>-0.32</b>	(0.44)	<b>2.49</b>	(0.14)	<b>-0.128</b>	(0.44)
<b>U.K.</b>	<b>11.43</b>	(0.02)	<b>13.70</b>	(0.01)	<b>0.835</b>	(0.02)
<b>U.S.</b>	<b>22.41</b>	(0.08)	<b>24.66</b>	(0.06)	<b>0.909</b>	(0.08)

Note: The estimates of the measures are median biased corrected, using the median of the empirical distribution generated by the bootstrap procedure. The probability that the estimate has the incorrect sign is in parenthesis.

Table 2 reports the (bias-corrected) estimates of  $\Delta P$ ,  $\Delta E$ ,  $Q$ , together with the probability that the estimated measures have the incorrect sign.<sup>30</sup> Out of the 21 countries that experienced a macro performance gain, 14 countries (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 variability 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.

<sup>30</sup>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 the number of bootstrap replications (1,000), and conversely for the case when the estimate is less than zero.

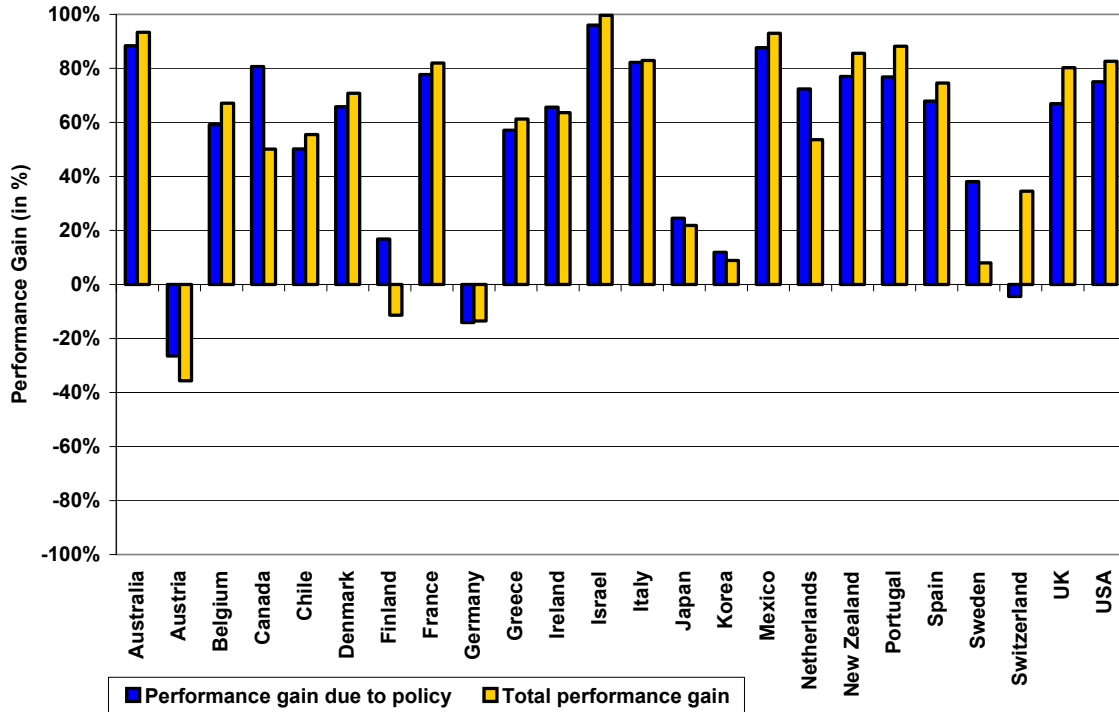
Looking at the final column, the results show that more efficient policy accounted for between 84% (U.K.) and 99% (Italy) of the improvement in overall macroeconomic performance. Six other countries (Canada, Ireland, Japan, Korea, Netherlands and Sweden) experienced both a performance gain ( $\Delta P > 0$ ) 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 4, 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 contribution to macro performance by the decrease in the variability of aggregate shocks has been insignificant.

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 variability 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.<sup>31</sup>

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<sup>31</sup>Using average inflation and log-linear trend for output as targets the contribution of policy is nearly identical to our baseline estimates. The only exceptions are Korea, Austria and Finland, since the first one shows a performance loss while the other two show a modest gain. Using H-P filtered inflation and log-linear trend for output as targets the contribution of policy for about half of the countries is smaller, but still more important than the contribution of the reduction of the shocks. Our main conclusions are thus robust to different inflation and output targets.

**Figure 4: Changes in Performance due to Policy**



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 3: Performance and Efficiency Changes over a range of values for inflation aversion**

Country	Macroeconomic Performance Gain (in %)	Contribution of policy to change in performance ( $Q=\Delta E/\Delta P$ )
<b>Australia</b>	[93.3%, 93.5%]	[0.945, 0.949]
Austria	[-70.5%, 17.7%]	[-0.747, 1.040]
Belgium	[49.5%, 86.4%]	[0.812, 0.992]
Canada	[43.9%, 60.6%]	[1.424, 1.763]
Chile	[52.4%, 58.8%]	[0.895, 0.912]
Denmark	[54.9%, 90.7%]	[0.894, 0.977]
Finland	[-119%, 69.0%]	[-0.488, 36.807]
France	[69.3%, 92.7%]	[0.907, 1.014]
Germany	[-46.8%, -3.9%]	[-2.231, -0.704]
Greece	[61.1%, 61.5%]	[0.892, 0.949]
Ireland	[41.2%, 88.0%]	[0.994, 2.673]
Israel	[99.4%, 99.7%]	[0.963, 0.965]
Italy	[80.7%, 84.7%]	[0.983, 0.997]
Japan	[2.7%, 25.7%]	[1.087, 2.765]
Korea	[-6.0%, 41.6%]	[-0.342, 3.314]
Mexico	[91.9%, 93.4%]	[0.941, 0.943]
Netherlands	[42.7%, 68.0%]	[1.217, 1.513]
New Zealand	[73.4%, 95.6%]	[0.883, 0.911]
Portugal	[84.5%, 90.7%]	[0.868, 0.873]
Spain	[64.6%, 82.1%]	[0.893, 0.920]
Sweden	[-53.8%, 54.6%]	[0.297, 45.013]
Switzerland	[3.8%, 47.6%]	[-9.652, 0.196]
U.K.	[80.1%, 80.3%]	[0.834, 0.835]
U.S.	[70.9%, 91.1%]	[0.880, 0.959]

Note: The estimates of the measures are median biased corrected, using the median of the empirical distribution generated by the bootstrap procedure. For the countries for which we set our baseline  $\lambda$  equal to 0.8, we consider a range of 0.65 to 0.95. For the four high inflation countries we consider a range for  $\lambda$  of 0.15 to 0.45.

Finally, as a robustness check to our choice of inflation aversion parameter, we examine how the estimates of changes in performance and policy efficiency change as we vary  $\lambda$ . For the countries for which we set  $\lambda$  equal to 0.8, we consider a range of 0.65 to 0.95. This is consistent with estimates obtained by Cecchetti and Ehrmann (2001) and Krause (2002). For the four high inflation countries, where the baseline value of  $\lambda$  was set to 0.3, we consider a range between 0.15 and 0.45. Results are reported in Table 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  $Q$ .<sup>32</sup>

<sup>32</sup>We note again that our results are robust to using estimates of  $\lambda$  obtained within our methodology, which are available upon request.

### 5.3 Robustness Exercises<sup>33</sup>

In our first exercise we restrict our 24-country sample to those countries that do not show a price-puzzle in the IRFs. The purpose is to analyze whether our results hinge on the arguably failure of the estimated transmission mechanism of a few countries.<sup>34</sup> Our main results about the contribution of monetary policy to the observed macroeconomic improvement hold for this restricted sample of 16 countries. Out of these countries, 13 of them experienced a macroeconomic performance gain and within them 10 experienced a reduction in the variability of shocks ( $\Delta S < 0$ ). For these countries, improved policy accounted for between 87% (Portugal) and 95% (Australia and France). For the 3 remaining countries (Canada, Ireland, and Netherlands), policy efficiency gain still more than offsets the higher variability of aggregate shocks. In summary, our conclusions are unchanged if we restrict our sample to those countries for which the IRFs do not show a price-puzzle.<sup>35</sup>

In the second exercise we reconcile our results with those of Stock and Watson (2003), which, using a different method, attribute the stabilization of output in the US after 1984 to "good luck" (reduction in the variability of shocks) rather than good policies (only about 10% contribution). The answer to reconciling their apparently opposite results with ours lies in the different subperiods considered by Stock and Watson (pre- and post-1984) and their different focus: they focus exclusively on output volatility. Applying our method to the same subperiods considered by Stock and Watson, and setting  $\lambda = 0$  (i.e. focus exclusively on output volatility) we are able to obtain very similar results to theirs: policy only explains about 18% of the reduction in output volatility for the US, and the macro performance gain is only 5%. If, as in our analysis,  $\lambda$  is set at 0.8, macro performance gain increases to 11% and policy explains 45% of it. Clearly, in our analysis, inflation volatility accounts for much of macro performance, and it is monetary policy that is responsible for that.

## 6 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

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<sup>33</sup>We thank the referees and the editor for suggesting these analyses.

<sup>34</sup>The countries that still present price-puzzles are 8: Israel, Italy, Japan, Korea, Sweden, Switzerland, UK, and the US.

<sup>35</sup>Interestingly, out of the 8 countries that showed ill-behaved IRFs, for 4 of them our measure of the contribution of policy to the change in macro performance (Q) was not significant in Table 2.

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.<sup>36</sup>

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

	<b>No. of countries</b>	<b>Macro Performance Change</b>	<b>Policy Efficiency Change</b>
Alesina, 1988	<b>15</b>	0.329 (0.23)	0.430 (0.11)
Grilli et. al.,1991	<b>18</b>	0.173 (0.49)	0.258 (0.30)
Cukierman and Lippi, 1999	<b>18</b>	-0.005 (0.99)	0.027 (0.92)

P-values are in parenthesis.

Table 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.<sup>37</sup>

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

<sup>36</sup>Cecchetti and Krause (2002) measure policy credibility by looking at past inflation performance.

<sup>37</sup>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.

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.

## 7 Conclusions

This paper proposes a general method 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 variability of shocks hitting the economy. Only in Austria and Germany did both policy deteriorate and the variability 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 paper 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.

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## Appendix I: Model Specification

The basic model consists of two equations. The aggregate demand equation (6) 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 (7) 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. External price inflation is measured by the annualized growth rate in the official exchange rate of the domestic currency vis-a-vis the currency of its main trading partner: Germany for the European countries, Japan for the Asian countries, and the U.S. for the rest. For some countries we also included additional lags, and dummy variables to account for currency crises, sharp recessions, or structural changes. Table A.1 provides a description of all the variables included in the aggregate demand - aggregate supply model for each country.

**Table A.1: Model Specification**

<b>Country</b>	<b>Explanatory variables in AD-equation (# of lags)</b>	<b>Explanatory variables in AS-equation (# of lags)</b>
<b>Australia</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1)
<b>Austria</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1)
<b>Belgium</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (2), Dummy variable (sharp output decline 86:I)	Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (exchange rate crisis 93:I-IV)
<b>Canada</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1)
<b>Chile</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (increase in money growth 92:I)
<b>Denmark</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (sharp output decline 86:II-87:I)	Industrial production (2), Inflation (2), External Inflation (1)
<b>Finland</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (exchange rate crisis 92:III-93:IV)
<b>France</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1)
<b>Germany</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1)
<b>Greece</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (sharp output decline 84:I-IV and 93:I-94:IV)	Industrial production (2), Inflation (2), External Inflation (1)
<b>Ireland</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (exchange rate crisis 93:I-IV and 95:I-IV)
<b>Israel</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1)
<b>Italy</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (exchange rate crisis 92:III-93:IV)
<b>Japan</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1)
<b>Korea</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1)
<b>Mexico</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (exchange rate crisis 83:I-IV and 95:I-II)
<b>Netherlands</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1)
<b>New Zealand</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (tax increases 85:I, 86:IV and 89:III)
<b>Portugal</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (exchan. rate crisis 92:IV-93:IV and 95:I-II)
<b>Spain</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (exchan. rate crisis 92:IV-93:IV and 95:I-II)
<b>Sweden</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1), Dummy variable (exchange rate crisis 92:III-93:IV)
<b>Switzerland</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1)
<b>UK</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1)
<b>USA</b>	Interest rate (2), Industrial production (2), Inflation (2), External Inflation (1)	Industrial production (2), Inflation (2), External Inflation (1)

## Appendix II: Data Description and 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).