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Measuring macroeconomic performance through a non-parametric Taylor curve

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ABSTRACT

Recently, frontier techniques have been utilised in the measurement of countries' macroeconomic performance by constructing a "production set" where the outputs are some macroeconomic indicators, while the inputs collapse to a unit scalar. In the present study, a different approach is proposed. The trade-off between the variability of inflation and of the level of activity (often defined as the Taylor Curve) is posited as the relevant policy frontier. This frontier is estimated through non-parametric techniques on a sample of 19 OECD countries during the 1960-99 period. There seems to be a definite role for cost-shocks, as well as for some supply-side characteristics, in shifting the variability trade-off. Also, the relative shadow price of the variability of inflation increases over time. Countries appear on the whole to have become slightly more efficient, but their performance has worsened, because the frontier has shifted upwards.

Keywords: inflation-output variability trade-off; labour market rigidities; policy efficiency

JEL classification: J63, J64, J65, E24

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Table of Contents

1 - Introduction

2 – Deriving the variability trade-off: the Taylor curve

3 – Measuring the variability trade-off: the existing evidence

4 – Measuring the variability trade-off: a new tack

5 – The empirical analysis

5.a The data and the estimation strategy

5.b The results

6 – Concluding remarks

References

1 - Introduction

One of the hallmarks of economics is the concept of a trade-off. This also applies within the field of monetary policy. During the 1960s and early 1970s, many economists and policymakers believed a central bank could achieve permanently lower unemployment by accepting permanently higher inflation. Attempts to exploit such a trade-off to gain the benefits of lower unemployment were, however, self-defeating. Rather than remaining stable at a new higher level, the inflation rate continued to increase as long as unemployment remained below the economy's long-run rate. Thus, experience has convinced most policymakers that no such trade-off exists.

This does not mean, however, that central banks do not face unemployment-inflation trade-offs as they implement monetary policy. Recent research in macroeconomics has increasingly focused on the trade-off between *the variability* of the level of activity and of the variability of inflation (see for instance Taylor, 1996, p. 186). Attempts to keep inflation within a very narrow band are supposed to increase fluctuations in real GDP and employment. Conversely, attempts to smooth business cycle fluctuations are believed to lead to wider fluctuations in inflation. Evaluating alternative policies in terms of their implications for the trade-off between GDP volatility and inflation volatility offers useful insights into some recent monetary policy debates. Many economists would argue that a single-minded focus on maintaining inflation within a very narrow band may lead to undesired real economic fluctuations. And conversely, attempts to smooth real fluctuations too actively will lead to excessively volatile inflation. The variability trade-off is also important for those countries that have moved to an inflation targeting policy regime since it is critical for determining the appropriate width of the inflation target. New Zealand, for example, initially defined its inflation target as 0 - 2% inflation. In 1997, however, this was widened to 0 - 3%. The Bank of England has a target inflation band of plus or minus 1% around its target of 2.5% inflation. The output-inflation variability trade-off is one of the key factors in determining the effects of changing the width of the inflation band. If the trade-off frontier is steep, for example, then reducing the variability of inflation causes little increase in GDP variability. In this case, a narrow target inflation band would be appropriate. A recognition of the variability trade-off shifts the focus from the level of inflation to questions of how wide the target band should be. Still, the precise nature of this trade-off, and even its actual existence, is a subject of debate in the literature.[1]

This paper brings new evidence to bear upon this issue, conforming to the following structure: in Section 2 we examine an analytical derivation of the variability trade-off, called the Taylor curve after J.B. Taylor. Section 3 surveys the existing evidence on the Taylor curve, which is based on econometric simulations. Section 4 examines the promise of a largely new approach to this issue, based on the estimation of a cross-country cross-period non-parametric frontier. In Section 5, this approach is implemented, and its results are discussed. Section 6 contains some concluding remarks.

[1] See Walsh (1998 , p. 2).

2 – Deriving the variability trade-off: the Taylor curve

Following Taylor (1994), consider three equations summing up the relations among real GDP, nominal rate of interest and rate of inflation:

$$y_t = -\beta (i_t - \pi_t - r^*) + u_t \tag{2.1}$$

$$\pi_t = \pi_{t-1} + \alpha y_{t-1} + e_t \tag{2.2}$$

$$i_t = \pi_t + gy_t + h (\pi_t - \pi^*) + r^f + v_t \tag{2.3}$$

where y_t is GDP measured as the percentage gap from its potential level; i_t is the short-term nominal rate of interest measured as a percentage; π_t the rate of inflation measured in percentage points; e_t, v_t, u_t are zero-mean shocks. The model parameters are π^*, r^t, r^*, α, β, g, h.

The first equation describes the inverse relationship between the real rate of interest and the deviations of real GDP vis-à-vis its potential level. These deviations depend on aggregate demand fluctuations: consumption, investment and net exports are assumed to depend negatively on the real rate of interest. Notice that for simplicity the actual, not the expected, rate of inflation is included in (2.1). The random variable u_t is a shift factor representing, among other things, changes in government purchases. When GDP equals its potential level ($y_t = 0$), the real rate of interest equals r^*, which is then defined as the equilibrium real rate of interest. The second equation describes price adjustment: inflation rises (falls) with a lag when GDP is above (below) its potential level. There are various rationales in the literature for this nominal rigidity. The random variable e_t represents price shocks. The third equation represents monetary policy in terms of the reaction of the central bank to deviations of inflation from π^* and to deviations of real GDP from its potential level. The policy instrument of the central bank is the short-term nominal rate of interest. Variable r^f is the implicit real rate of interest in the reaction function of the central bank. The random variable v_t represents monetary shocks.[2]

The long-run values of real GDP, inflation and nominal rate of interest are found by setting to zero the rate of inflation and the random shocks. We get:

$$y = 0 \tag{2.4}$$

$$i = r^* + \pi \tag{2.5}$$

$$\pi = \pi^* + (r^* - r^f) / h \tag{2.6}$$

Equation (2.4) makes it clear that in the present model there is no long-run trade-off between the rate of inflation and the GDP gap from its potential level. Keeping in mind Okun's law, this implies that no long-run trade-off exists between the rates of inflation and unemployment. While it is certainly possible for potential GDP (or for the natural rate of unemployment) to be dependent on the rate of inflation, there is some strong

[2] Equation (2.3) could also be interpreted as the result of a monetary policy with a fixed growth rate of the money supply.

evidence to the contrary and the structure of our model is meant to capture the spirit of these results.

In order to derive the trade-off between the variability of the GDP gap and the variability of inflation, first substitute (2.3) into (2.1):

(2.7) $$y_t = -c(\pi_t - \pi^*) - (c/h)(r^f - r^*) + (u_t - \beta v_t)/(1 + \beta g)$$

where $c = \beta h/(1 + \beta g)$. This expression simplifies if $r^f = r^*$. Then substitute equation (2.7) into (2.2). This yields:

(2.8) $$\pi_t - \pi* = (1 - \alpha c)(\pi_{t-1} - \pi^*) - (\alpha c/h)(r^f - r^*) + \alpha (u_{t-1} - \beta v_{t-1})/(1 + \beta g) + e_t$$

The variance of the rate of inflation can easily be obtained from (2.8), and from this the variance of the GDP gap can be obtained using (2.7). Now, suppose the aim of the central bank is to minimise the following quadratic loss function:

(2.9) $$L = E[\lambda(\pi_t - \pi^T)^2 + (y_t)^2]$$

where π^T is the (exogenously determined) target rate of inflation and the other variables have already been defined. Central bank policy can now be treated as the solution to a control problem where the level of the short-term nominal rate of interest must be chosen in order to minimise (2.9). Formally, the optimal policy reaction function is found by minimising (2.9) subject to the constraints imposed by the structure of the economy as described by (2.1)-(2.3). For a given structure of the economy, and a given λ, this yields a point characterised by the combination of the minimum variances of inflation (around a given target rate) and of GDP (around its potential value). Repeating the same minimisation exercise under different values of λ, we are able to trace a locus of these minimum-variance points, the policy efficiency frontier.

To get a more intuitive grasp of this frontier, note that there are three kinds of disturbances hitting the economy; the demand shocks u_t[3] and v_t, and the cost shock e_t. The demand shocks move GDP (relative to its potential level) and inflation in the same direction, while the cost shock moves GDP and inflation in opposite directions. A policy relying on the short-term nominal rate of interest is akin to a demand shock inasmuch as it can only move GDP and inflation in the same direction. Given a quadratic loss function and a linear structure of the economy, optimal policy is also represented by linear rules. In this case, the optimal policy response to demand shocks is to offset them one-for-one, meaning that the variances of GDP and inflation on the policy frontier are not affected by the variance of demand shocks. The same cannot be said for cost shocks. By moving GDP and inflation in opposite directions, they force central bank to face a trade-off. As a consequence, the optimal policy response to a cost shock cannot be of a one-for-one nature, and the variances of GDP and inflation on the policy frontier are affected by the variance of cost shocks.

[3] A surprising feature of this kind of literature is that, within this literature, u_t also represents shocks affecting the potential GDP level (such as TFP shocks). Indeed, the impact of these shocks on the GDP gap can be fully negated through demand management. Hence they cannot be considered as a frontier shifter: their variance can change indefinitely without affecting the optimal policy point.

In our simple example, the policy frontier can be found positing to zero both u_t and v_t. A variability trade-off easily obtains by varying *c*, which depends on the policy parameters *h* and *g*. Indeed, monetary policy determines $-(1 + \beta g)/\beta h$, the slope of equation (2.7), the aggregate demand curve, through parameters *g* and *h*. A lower *h* or a higher *g* make the curve steeper, and vice versa.[4] If the aggregate demand curve is steeper, then the GDP gap following a price shock is relatively smaller; if the curve is flatter the GDP gap following a price shock is larger. Clearly the variance of the GDP gap is lower when the aggregate demand curve is steeper, that is when *h* is small and *g* is large. Fig. 1 depicts this variability trade-off.

The variance[5] of the rate of inflation is on the vertical axis, while the variance of the GDP gap is on the horizontal axis. As short-term interest rates respond more to inflation, (larger *h*) and less to the GDP gap (smaller *g*), the aggregate demand curve gets flatter. Hence, the variance of the GDP gap increases and the variance of inflation decreases.[6] It also follows from this discussion that a change in the variance of cost shocks would shift the trade-off frontier; an increase in the volatility of energy prices, for example, would lead to more inflation and GDP variability.

Following a string of extremely influential works by J.B. Taylor, this variability trade-off represents the new policy benchmark for central bankers. For example, Taylor (1993) has suggested that the Fed behaviour in recent decades has been characterised by a rule relating the federal funds rate to movements in inflation and the output gap:

$$i_t = \pi_t + g\gamma_t + h\,(\pi_t - \pi^*) \tag{2.10}$$

Using this rule for determining the funds rate, for given values for *g* and *h* and a given structure of the economy, one can find a point characterised by the combination of the minimum variances of inflation and GDP gap. By then changing the values for *g* and *h*, a trade-off emerges between the variances of inflation and GDP gap along the above described lines. In a similar manner, the frontier associated with a different rule for adjusting the funds rate, such as one that responds to nominal income movements, can be derived. The GDP-inflation variability trade-off for two hypothetical policy rules is illustrated in Fig. 2.

The rule that produces the dashed trade-off frontier can be described as inefficient; for any given GDP variance, the policy rule that produces the solid line results in lower

4 Note that, while in the present model only the ratio between *g* and *h* affects the variance trade-off, the absolute magnitudes of these parameters are also of high policy relevance. For instance, raising both *g* and *h* very high would probably not be a good policy, as it could result in large fluctuations in the rates of the interest.

5 Taylor actually measures variability through the standard deviations of inflation and GDP gap. Svensson (2002) argues convincingly that formulating the trade-off in terms of variances is analytically more convenient.

6 From Fig. 1 it may seem that the variance of inflation is not influenced by changes in *g* or *h*. This is not true, however, because the policy rule chosen has an impact on the variance of inflation by affecting the speed at which GDP returns to its potential level.

Fig. 1 - The GDP-inflation variability trade-off

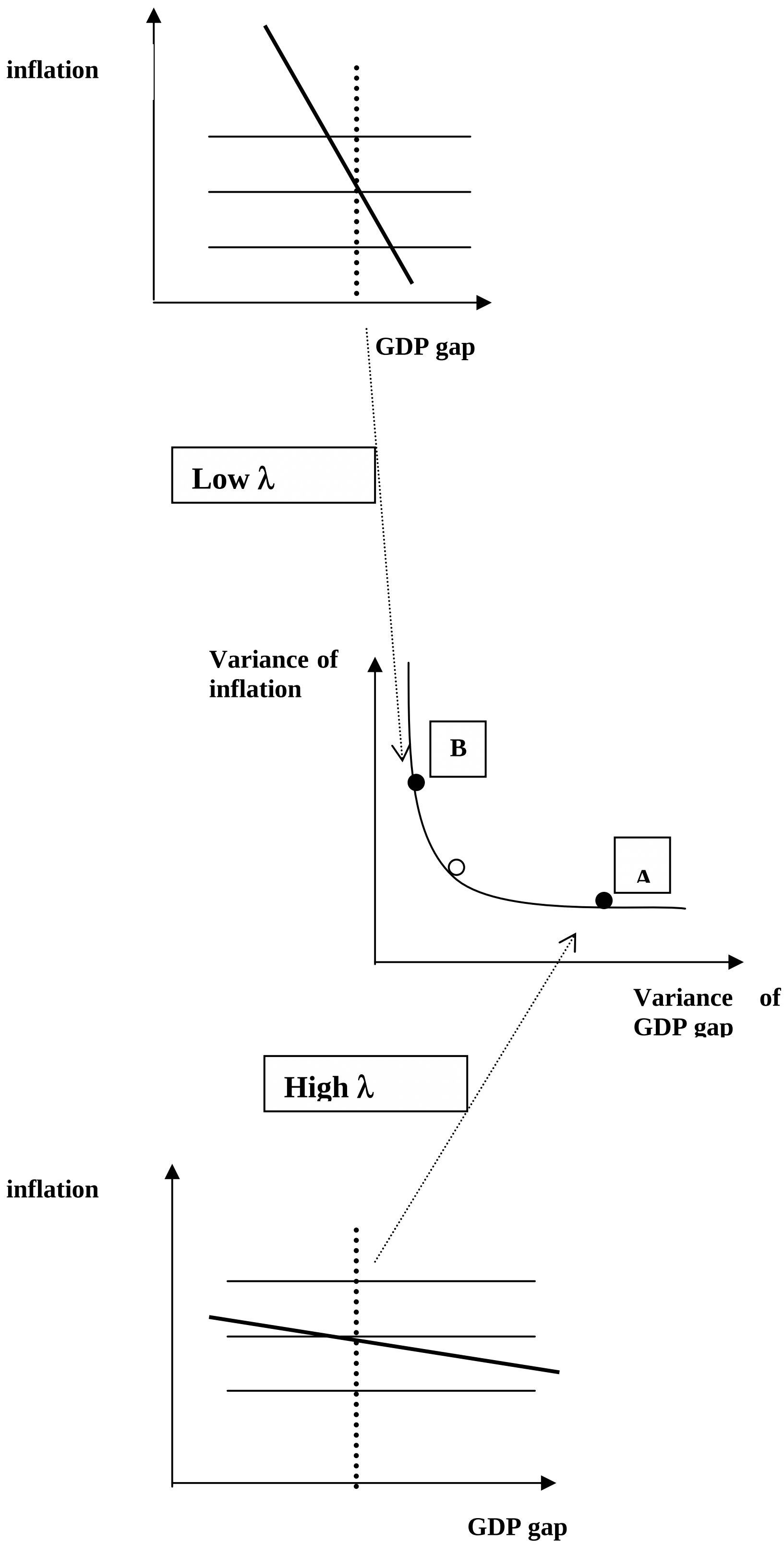
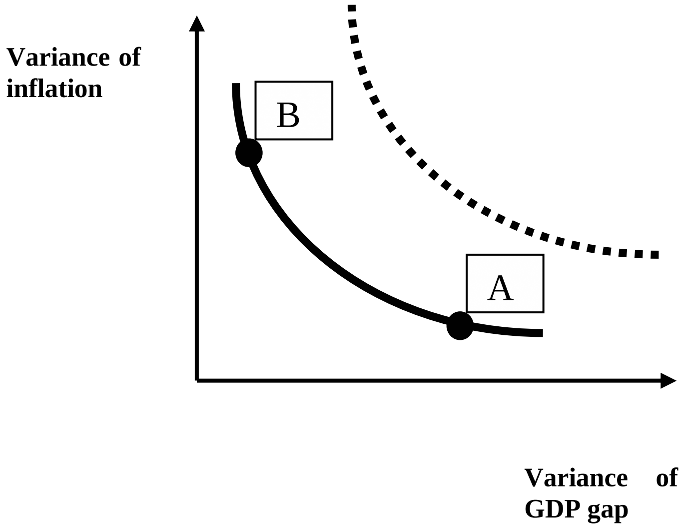


Fig. 2 - The variability trade-off for two hypothetical policy rules



inflation variance. Once the efficient trade-off frontier has been found, policymakers must weigh the relative costs of GDP variability versus inflation variability in choosing a point on the frontier. If inflation variability is viewed as more costly than GDP variability, a point such as A might be optimal, while point B would be optimal if the costs of GDP variability are assessed more highly. This two-step approach, finding the efficient frontier and then deciding which point to pick, is useful in separating two distinct aspects of policy choice. On the one hand, the structure of the economy and the nature of economic disturbances will define the efficient frontier. On the other hand, the factors that determine the point on the frontier to be chosen depend on the assessment of the relative costs of inflation and GDP variability.

3 – Measuring the variability trade-off: the existing evidence

Virtually all of our knowledge of variability trade-offs comes from simulations of models designed to mimic the behaviour of the major industrialised economies. These models incorporate realistic inflation and GDP adjustment so that they can be used to study the variability trade-off implied by different rules for conducting monetary policy. Fuhrer (1997), Ball (1999), Batini and Haldane (1999), Rudebusch and Svensson (1999) provide important examples of this type of research, employing models of the US and of the UK economy. The evidence from simulations can be used to determine the nature of the volatility trade-off that arises under a particular policy rule and to evaluate alternative policy rules.

Now, the notion that attempting to smooth fluctuations in real GDP will lead to more inflation variability is fairly intuitive. But does such a variability trade-off actually exist? Simulations of economic models reveal such a trade-off, but economists disagree about which model best captures the true behaviour of the economy, and these disagreements mean that there is no consensus about the true trade-off faced by policymakers. It is also difficult to find evidence of the trade-off in the data from actual economies. There are several reasons why the empirical evidence is inconclusive. The chief problem is that each point on the trade-off frontier is associated with a specific way of conducting monetary policy. If policy has been conducted in a stable and efficient fashion over several years, then the observed volatility of GDP and inflation would provide an observation on a single point on the trade-off frontier. Evidence on just a single point does not provide information on the entire trade-off frontier.

Within the existing literature, we will now focus on the studies carried out by Cecchetti and his associates (Cecchetti, 1998; Cecchetti et al., 1999; Cecchetti and Ehrmann, 2000; Cecchetti et al., 2001), because of their simple and elegant structure and because of their (to some extent, deceptive) similarity with the endeavour here undertaken. Basically we will describe the analysis in Cecchetti et al. (2001), with some occasional references to the other works. In Cecchetti et al. (2001) a sample of 23 industrialised countries is taken into account for the 1980s and the 1990s. There has been a marked improvement in the macroeconomic conditions across these periods, in particular as far as inflation is concerned. From a mean rate of 10.8% in the 1980s these economies progressed in the 1990s to 3.4%.

The main aim of the analysis is to consider this change in macroeconomic performance and to attempt its decomposition in shifts of the policy frontier (associated to a change in the variance of cost shocks) and in efficiency changes (shifts vis-à-vis the frontier). To do so Cecchetti et al. (2001) start from the quadratic loss function already seen in Section 2:

(3.1) $$= \mathrm{E}\,[\,\lambda\,(\pi_t - \pi^T)^2 + (1-\lambda)\,(y_t)^2\,]$$

Indeed, to measure macroeconomic performance the loss associated to a given performance point on the frontier must be computed, and to do an estimate of the parameter λ is needed. The following procedure is adopted in order to get it. Any given performance point is characterised by the optimal GDP and inflation variances found at the intersection of the policy frontier with a ray going from the origin to the performance point itself.

We thus assume, by the axiom of Revealed Preferences, that the parameter λ characterising any given performance point is the slope of the policy frontier in correspondence of this intersection. Now macroeconomic performance P_i is given by the observed GDP and inflation variances weighted by this particular λ, denoted λ_i:

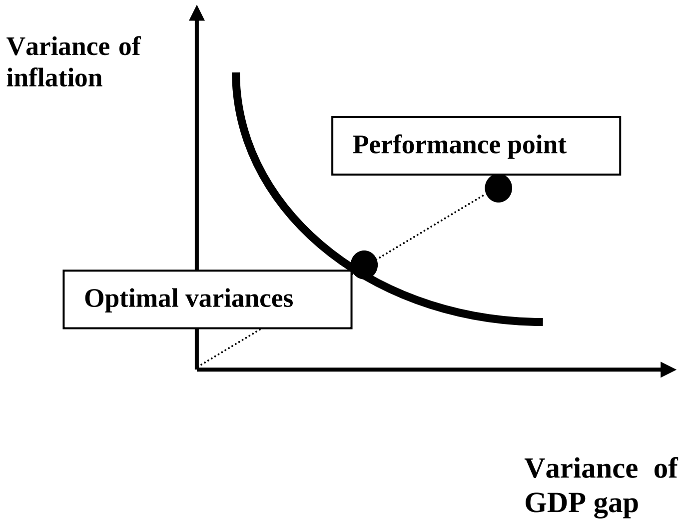
(3.2) $${}_i = \mathrm{E}\,[\lambda_i\,(\pi_t - \pi^T)^2 + (1-\lambda_i)\,(y_t)^2\,]$$

The variation in macroeconomic performance, $\Delta\, P_{it}$, is defined as P_{it-1} - P_{it}. Subsequently, $\Delta\, P_{it} > 0$ stands for an *improvement* in macroeconomic performance. This improvement can be brought about either by a shift toward the frontier, or by a shift of the frontier, or by a combination of both. Shifts of the frontier, that are one and the same thing as cost shocks, are given by:

(3.3) $\quad {}_{i} = E\,[\lambda_i\,(\pi^*_t - \pi^T)^2 + (1 - \lambda_i)\,(y^*_t)^2\,]$

where π^*_t and y^*_t denote the values of inflation and GDP subsequent to cost shocks. since $\Delta\, S_{it} = S_{it} - S_{it-1}$ is the measure used to quantify the variations of cost shocks, it follows that $\Delta\, S_{it} > 0$ stands for a larger variance of cost shocks.

Fig. 3 - Estimating the parameter λ from revealed preferences



Now, the country's macroeconomic efficiency can be defined comparing actual performance with the optimal variance point. Macroeconomic *in*efficiency is defined as:

(3.4) $\quad {}_{i} = P_i - S_i$

If I_i increases over time, this means that the country's macroeconomic efficiency deteriorates, and vice versa.

In order to implement these measures empirically, a small macro dynamic model is estimated over the two periods 1982-89 and 1990-97. This model comprises an aggregate demand and an aggregate supply curve, which are estimated through OLS country by country. Using these estimates and an unrestricted policy reaction function (with the rate of interest as the policy instrument) a performance point and an optimal frontier point can be singled for each country in a given period.

More formally, suppose that the central bank selects the rate of interest i_t that minimises the loss function (3.1), subject to the structure of the economy as described by:

(3.6) $\quad {}_{t} = BY_{t-1} + c i_{t-1} + DX_{t-1} + v_t$

The quadratic nature of the problem ensures the linearity of the solution:

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

where Γ is the vector of the coefficients representing the reaction of the monetary authority to changes in GDP and inflation, while Ψ is a constant term depending on B, c, D and the target values of inflation (and eventually GDP). The control problem is solved finding Γ from:

$$=-(c'Hc)^{-1}c'HB\ , \tag{3.8}$$

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

Following this procedure for a given λ yields an optimal variance point. By varying λ a whole policy frontier can be traced, and measures P_i , S_i and I_i obtained along the above described lines.

The empirical results reveal that all countries, with the exception of Germany, Austria and Sweden, had significant improvements in economic performance. Also, in 20 out of the 23 countries under examination, policy efficiency improves. Indeed the results suggest that higher efficiency has been more instrumental than the lower variance of cost shocks in achieving a better macroeconomic performance.

4 – Measuring the variability trade-off: a new tack

One way around the estimation problem illustrated in the previous section is to look at the experiences of many different countries. If countries have similar economic structures, have faced similar disturbances, and have operated on the efficient frontier, but have differed in the choices policymakers have made between GDP and inflation stability, then historical patterns of different countries would provide evidence on the GDP and inflation variability trade-off. Unfortunately, actual economies have different economic structures, have experienced different disturbances, and have conducted policy in different ways. Thus, it is difficult to identify a variability trade-off using the historical experiences of a cross-section of countries.

Yet, consider the following research strategy. In recent years, some attention has been paid to the utilisation of frontier techniques to the measurement of countries' macroeconomic performance throughout a given period. In all these works (see for instance Lovell, 1995; or Lovell *et al*., 1995), performance is assessed by constructing a "production set", where the outputs are basically some indicators of growth (or GDP per capita), price stability, employment, and trade balance, while the inputs are the services provided by the countries' helmsmen (implying under some simple assumptions that the input vector collapses to a scalar of value one for every country in every year). Then, (technical) efficiency measures are computed through some non-parametric techniques such as FDH or DEA. Some obvious improvements on this kind of analysis would rely on the choice of outputs through a proper economic model, and on the adoption of a more articulate input-set than the simple representation given above of the helmsman’s services. There are some reasons to believe that applying frontier analysis to the estimation of the Taylor curve seems to be able to provide the required improvements. The trade-off involves two well-defined magnitudes that are positive by definition (and thus amenable to the province of production analysis). There is a lively ongoing debate suggesting plenty of articulate specifications of the helmsman's services. In order to supersede the simple representation of inputs as the services provided by the countries' helmsmen, one could rely on the indicators of governance suggested by the recent theoretical and empirical literatures on the labour market (Layard *et al.*, 1991; Layard and Nickell, 1999; Blanchard and Wolfers, 2000). Furthermore, it seems that frontier analysis is ideally suited to answer the kind of questions that have been recently asked within the debate on the Taylor curve (Cecchetti *et al.*, 2001): is there an improvement in the trade-off? Has the frontier shifted or has monetary policy become more efficient?

More precisely, the empirical strategy here proposed is that in order to gauge the existence of a cross-country Taylor curve, frontier analysis is applied to a production set where the variability of inflation and the level of activity are taken as inputs (they are "bads"), and various indicators of cost-shocks, supply-side structure and policy stance are considered as outputs (perhaps it would be better to say frontier shifters). The policy frontier is to be estimated through non-parametric techniques: these techniques easily allow to deal with a multi-input multi-output set-up, do not incur any simultaneity problem, and do not make any restrictive assumption about functional form (and then on the eventual interactions between the target variables and their exogenous determinants). Also, the non-parametric approach easily allows for high behavioural heterogeneity across time and countries. The main drawback of this approach is that it makes it difficult to allow for the stochastic noise in the data. Within the non-parametric approach, DEA is to be preferred,[7] since we are highly interested in calculating shadow prices. These shadow prices allow to assess empirically which is the relative weight policymakers put upon the variability of inflation and of the GDP gap. A graphical illustration of the DEA approach is provided in Fig. 4.

Formally, the postulates utilised to build the production possibility set $Z_{BCC}(Z°)$ are:

1. strong free input and output disposal;
2. convexity:

$$\forall(\mathbf{x}_i,\mathbf{y}_i)\ e\ (\mathbf{x}_j,\mathbf{y}_j)\in Z_{BCC}(Z°),$$
$$\forall 0\le\alpha\le 1,\quad \begin{pmatrix}\mathbf{x}\\ \mathbf{y}\end{pmatrix}=\alpha\begin{pmatrix}\mathbf{x}_i\\ \mathbf{y}_i\end{pmatrix}+(1-\alpha)\begin{pmatrix}\mathbf{x}_j\\ \mathbf{y}_j\end{pmatrix}\in Z_{BCC}(Z°)$$

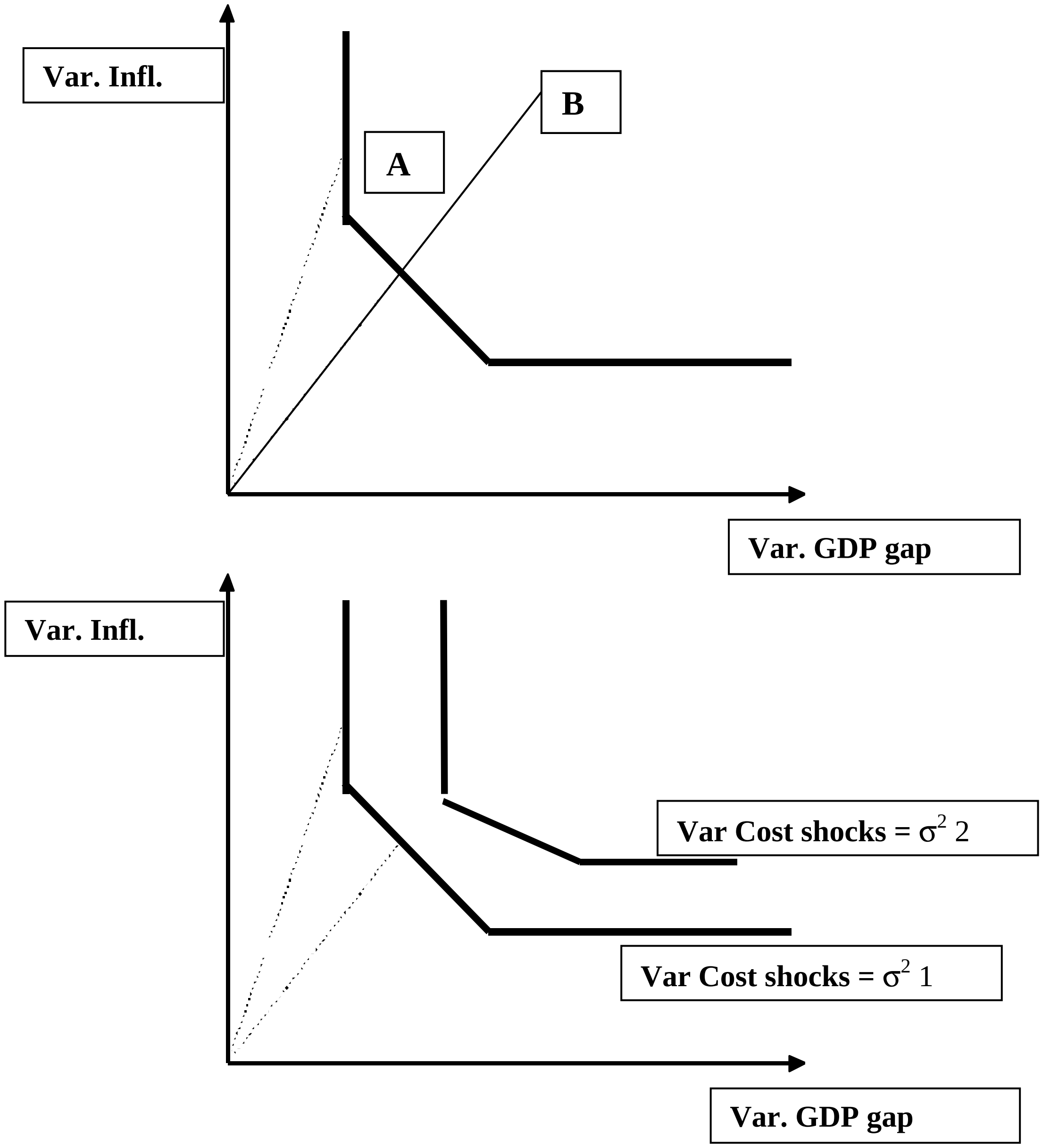
3. the vector $\mathbf{0}\notin Z_{BCC}(Z°)$.

The production possibility set is defined by:

$$\hat{Z}_{DEA-V}(Z°)=\Big\{(x,y)\in R^{N+M}\ :$$
$$y\le\sum_{j=1}^{N}\gamma_j y_j;\ x\ge\sum_{j=1}^{N}\gamma_j x_j;\ \sum_{j=1}^{N}\gamma_j=1;\ \gamma_j\ge 0,\ j=1,\ldots,N\ \Big\}$$

[7] A very recent and complete introduction to DEA is given in Cooper *et al.* (2000).

Fig. 4 - T**he DEA approach. A graphical illustration**



and its frontier is characterised by variable returns to scale. The *input-saving* technical efficiency score DF_I of the i-th observation, λ_i, is obtained from the *input-oriented* model BCC$_P$-I):[8]

[8] Formally, an output-oriented model can be set up, and output-increasing efficiency measures obtained. However, in the present context we need be interested only in the input-oriented model.

$$
\begin{aligned}
&\mathrm{BCC}_P\text{-I}\ (x_i, y_i):\\
&\min_{\lambda_i,\ \gamma_j} \lambda_i\\
&\text{s.t.}\\
&y_{mi} \le \sum_j \gamma_j\ y_{mj}, \qquad m = 1, ..., M\\
&\lambda_i x_{ki} \ge \sum_j \gamma_j\ x_{kj}, \qquad k = 1, ..., K\\
&\lambda_i \ge 0,\ \sum_j \gamma_j = 1, \quad j = 1, ..., N
\end{aligned}
$$

Usually, observations are dominated by convex combinations of efficient observations situated on the frontier.

The identification problem has been above formulated in its *envelopment form*. The dual expression, the *multiplier form*, is:

$$
\begin{aligned}
&BCC_D^I\ (x_i, y_i):\\
&\max_{\mu_i, \nu_i, \omega_i} \mu_i y_i + \omega_i\\
&\nu_i x_i = 1\\
&\mu_i y_i - \nu_i x_i + \omega_i \le 0\\
&\mu_i \ge 0, \nu_i \ge 0
\end{aligned}
$$

providing information on the shadow prices ν_i and μ_i; the ratios among the latter are the input and output marginal rates of substitution.

Although DEA cannot allow for stochastic noise in the data generating process, this is not tantamount to say that no inference can be carried out within this framework. In particular, the significance or a given input or output in the production set can be tested using the procedures described in Banker (1996). The main idea behind these procedures can be summed up as follows. Let *X* and *Y* be the input and output vectors of a baseline model and let *Z* be the variables whose significance is to be tested. Using DEA, one can estimate $\hat{\theta}(X,Y)$ and $\hat{\theta}(X,Y,Z)$, that is the efficiency scores without and with Z in the production set. If no assumptions are maintained about the probability distributions of the efficiency scores, a Kolmogorov-Smirnov test can be applied to:

$$
T_{KS} = \max \left(\hat{F}(\hat{\theta}_j(X, Y)) - \hat{F}(\hat{\theta}_j(X, Y, Z)) \;\middle|\; j = 1,..., N \right)
$$

the maximum vertical distance between the cumulative distribution functions of the efficiency scores $\hat{\theta}(X,Y)$ and $\hat{\theta}(X,Y,Z)$. If the variable Z significantly affects this distance, it is deemed to belong to the production set.

5 – The empirical analysis

We first describe our data-set, then the way in which DEA has been adapted to this rather unusual field of application. Finally we provide a description of our results.

5.a The data and the estimation strategy

To repeat, in order to gauge the existence of a cross-country Taylor curve, frontier analysis is applied to a production set where the variability of inflation and of the GDP gap are taken as inputs (they are “bads”), and various indicators of cost-shocks, supply-side structures, and policy stance are considered as frontier shifters. The empirical application here provided relates to the measurement of macroeconomic performance during the 1960-99 period in a sample of 19 OECD countries (data are mainly taken from the OECD database).

As said above, usual methods provide evidence on just a single point of the entire trade-off frontier. One way around this problem is to look at the experience of many different countries controlling for their different economic structures and disturbances. Accordingly, the “production set” should be conditioned on all these factors, relying on a battery of Banker tests (Banker, 1996) to assess their relative significance. It is in this respect that the literature on labour market performance (Layard *et al*., 1991; Layard and Nickell, 1999; Blanchard and Wolfers, 2000) is useful. It suggests a group of supply-side variables widely believed to be important in dictating the response of aggregate prices and quantities to excess demand.

Series for the variance of inflation (CPI and GDP deflator) and of the GDP gap (Hodrick-Prescott output gap) are taken from the OECD database for 19 OECD countries over the 1960-99 period. Series for the cost shocks are provided by the variance of the real oil prices weighted by oil import shares, and of the labour demand shift indicator suggested in Blanchard and Wolfers (2000). The impact of the former factor (affecting the supply price of labour both directly and through the productivity slowdown; see on this Blanchard, 1997, pp. 91; 116-119) is supposed to have been paramount roughly from 1975 to 1985, while the other factor has been more relevant in the late 1980s and the early 1990s, particularly for the Continental European economies (again see on this Blanchard, 1997, especially pp. 91-92; 119-121).

Variances are calculated on annual data over eight sub-samples, each one of them five-year long. Indicators of supply-side structure, taken from various sources, are available over the same sub-samples. We use a pooled sample: the eight sub-samples must be pooled together to reach a number of observations (allowing for some missing values, equal to 137), that makes inference reasonably sound. The supply-side factors utilised, as well as their sources, are indicated in Tab. 5.1.

5.b The results

We take a baseline specification (the variance of *GDP deflator inflation* and of *GDP gap* as inputs, the variance of the *real oil prices* and of the *labour demand shift* as frontier shifters).[9] The two baseline shifters, the variance of the *real oil prices* and of the *labour demand shift*, were tested vis-à-vis a specification with no shifter and found highly significant. The significance of various other shifters (basically, indicators of supply-side structure) is assessed against this baseline model.

TABLE 5.1 – The Significance of Supply-Side Characteristics

UNRESTRICTED MODEL	***Banker K-S Test (P-value)***
Baseline + Union Coverage (*Blanchard and Wolfers, 2000*)	*0.385*
Baseline + Union Density (*Ebbinghaus and Visser, 2000*)	*0.284*
Baseline + Employer-Union Coordination (*Nickell et al., 2001*)	*0.192*
Baseline + Labour tax rate (*Nickell et al., 2001*)	*0.236*
Baseline + Employment Protection Index (*Blanchard and Wolfers, 2000*)	*<u>0.040</u>*
Baseline + Unempl. Benefit Duration (*Blanchard and Wolfers, 2000*)	*0.150*
Baseline + Unempl. Benefit Retention Ratio (*Blanchard and Wolfers, 2000*)	*0.150*
Baseline + Ownership Occupation Ratio (*Nickell et al., 2001*)	*<u>0.021</u>*

There is a clear role for some supply-side characteristics in shifting the variability trade-off. It turns out that the preferred specification includes as shifters (beside the variance of real oil prices and of the labour demand shift), the Employment Protection Index (EPI) and an index of ownership occupation.[10] Both variables are believed in the literature to be related with the persistence of shocks (Blanchard, 1999; Belot and van

[9] Things do not change appreciably if the production set is based upon the variance of CPI inflation and of the GDP gap. Results are available on request.

[10] Oswald (1997) suggests that barriers to geographical mobility, as reflected in the rate of owner occupation of the housing stock, play a key role in determining unemployment. He finds that changes in owner occupation (relative to private renting) represent a significant barrier to labour mobility.

Ours, 2001). What about having some further information on the performance of single countries? Consider Tab. 5.2, where we give the average efficiency scores throughout the whole period:

TABLE 5.2 – Assessing the Role of Supply-Side Characteristics

	Baseline	**Baseline plus** Empl. Prot. Index Owner. Occ. Ratio
Australia	0.37	0.64
Austria	0.55	0.66
Belgium	0.45	0.59
Canada	0.30	0.37
Denmark	0.48	0.52
Finland	0.29	0.36
France	0.56	0.63
Germany	0.59	0.67
Ireland	0.12	0.79
Italy	0.27	0.88
Japan	0.49	0.64
Netherlands	0.52	0.65
Norway	0.57	0.71
New Zealand	0.52	0.73
Spain	0.26	0.92
Sweden	0.28	0.52
Switzerland	0.68	0.68
UK	0.27	0.31
USA	0.58	0.72
Average Efficiency Scores	0.42	0.63

From Tab. 5.2, it can be clearly seen that the policy efficiency of countries such as Ireland, Italy and Spain, which perform very badly as far as EPI and labour mobility are concerned, improves a lot once full allowance is made for this handicap.

Having fully allowed for the role of cost-shocks and supply-side characteristics in shifting the variability trade-off, we provide measures for the following indicators:

λ_t, the relative shadow price of inflation variance

$\dot{E}_t$, the percentage change in efficiency scores $\dfrac{E_t - E_{t-1}}{(E_t + E_{t-1})/2}$

$\dot{P}_t$, the percentage change in macro performance, measured as $\dfrac{P_{t-1} - P_t}{(P_t + P_{t-1})/2}$,

where $P_t = [\, \lambda\, var\, (\pi_t) + var\, (y_t)\,]$

TC_t, the frontier shift, measured as $\dot{P}_t - \dot{E}_t$.

Median values for these indicators are shown in Tab. 5.3.

TABLE 5.3 – Median Values for Efficiency Changes, Frontier Shifts, Performance Changes

	$\dot{E}_t$	TC_t	$\dot{P}_t$
1960-65	0.00	-0.08	-0.08
1965-70	-0.05	0.38	0.33
1970-75	0.54	-0.93	-0.39
1975-80	-0.60	0.01	-0.59
1980-85	0.19	0.27	0.46
1985-90	-0.11	-1.13	-1.24
1990-95	0.08	1.00	1.08
Cumulative Sum	0.05	-0.47	-0.42

Throughout the period under consideration, countries appear to have become slightly more efficient (on average), but their performance on the whole has worsened, because the frontier has shifted upwards. The latter phenomenon is easily explained through Tab. 5.4, where we provide mean values for the cost-shock variances. Also, the (median) relative shadow price of the variance of inflation has risen in time (at least with respect to the 1970s), well in agreement with various kinds of evidence on the matter.

Now, what about assessing the recent move of some countries to Inflation Targeting, as well as the inception of the EMU? About the role of the EMU, consider in Tab. 5.5 the medians of $\dot{E}_t$ and λ_t for EMU and non-EMU countries (from 1980-85 onwards):

It turns out that countries within and outside the EMU have shown similar preferences for variance of inflation vis-à-vis GDP gap. Yet, the macro policy efficiency of EMU countries has been remarkably better. Further research will try to elucidate whether the source of this better performance mainly lies in more accurate demand management or in the insulation from demand shocks secured by the monetary union.

TABLE 5.4 – Period Means for Cost-Shock Variances, Period Medians for λ_t

	Variance of Oil prices	Variance of Labour demand shift	λ_t
1960	0.16	0.99	3.06
1965	0.27	2.28	0.85
1970	176.11	2.89	0.08
1975	221.68	2.73	0.25
1980	124.01	2.25	0.84
1985	78.50	2.51	2.92
1990	23.21	2.63	3.44
1995	10.38	2.04	2.32

TABLE 5.5 - Median Values for $\dot{E}_t$, Changes in λt

EMU vs. Non-EMU Countries

	$\dot{E}_t$	$\Delta\lambda_t$
EMU Countries	0.11	-0.11
Non-EMU Countries	-0.08	-0.08

As for Inflation Targeting, consider in Tab. 5.6 the medians of $\dot{E}_t$ and λ_t for targeting and non-targeting countries (from 1985-90 onwards):

TABLE 5.6 - Median Values for $\dot{E}_t$, Changes in λ

Inflation Targeting vs. Non-Inflation Targeting Countries

	$\dot{E}_t$	$\Delta\lambda_t$
Inflation Targeting Countries	0.00	-0.04
Non-Inflation Targeting Countries	0.20	-0.22

Here, a behavioural difference emerges: Inflation Targeting countries have stuck more solidly to the shift in preferences (toward more stable inflation) materialising at the outset of the 1980s. Yet, their macro policy efficiency has not significantly been affected by this move. On the other hand, it seems that non-Targeting countries have taken advantage of their greater freedom, achieving a better policy performance. On this matter too, further research is needed.

6 – Concluding remarks

The trade-off between the variability of inflation and of the level of activity (often defined as the Taylor Curve) is posited in the present paper as the relevant policy frontier for the assessment of macroeconomic performance. This frontier is estimated through non-parametric techniques on a sample of 19 OECD countries during the 1960-99 period. A definite role emerges for cost-shocks, as well as for some supply-side characteristics, in shifting the variability trade-off. Also, the relative shadow price of the variance of inflation is higher in recent years, well in agreement with various kinds of evidence. Countries appear to have become slightly more efficient on average, but their performance has worsened, because the frontier has shifted upwards.

One of the advantages of the approach here proposed is the possibility to bridge the gap between the Taylor curve literature and the strand of literature that emphasises the relationships between unemployment and institutional factors. The impact of the latter on the Taylor curve can in fact be straightforwardly assessed, and the results suggest that structural and institutional factors are indeed an important element in explaining cross-country heterogeneity of the variability trade-off. Once proper allowance is made for these factors in shifting the trade-off, the policy performance of countries such as Ireland, Italy and Spain, which perform very badly as far as EPI and labour mobility are concerned, improves a lot.

In future work, more recent data are to be constructed and used: this relates to other indicators of supply-side structure and of policy stance, as well as of nominal inertia. A deeper assessment of the recent move of some countries to inflation targeting, as well as of the inception of the EMU, is also highly needed.

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