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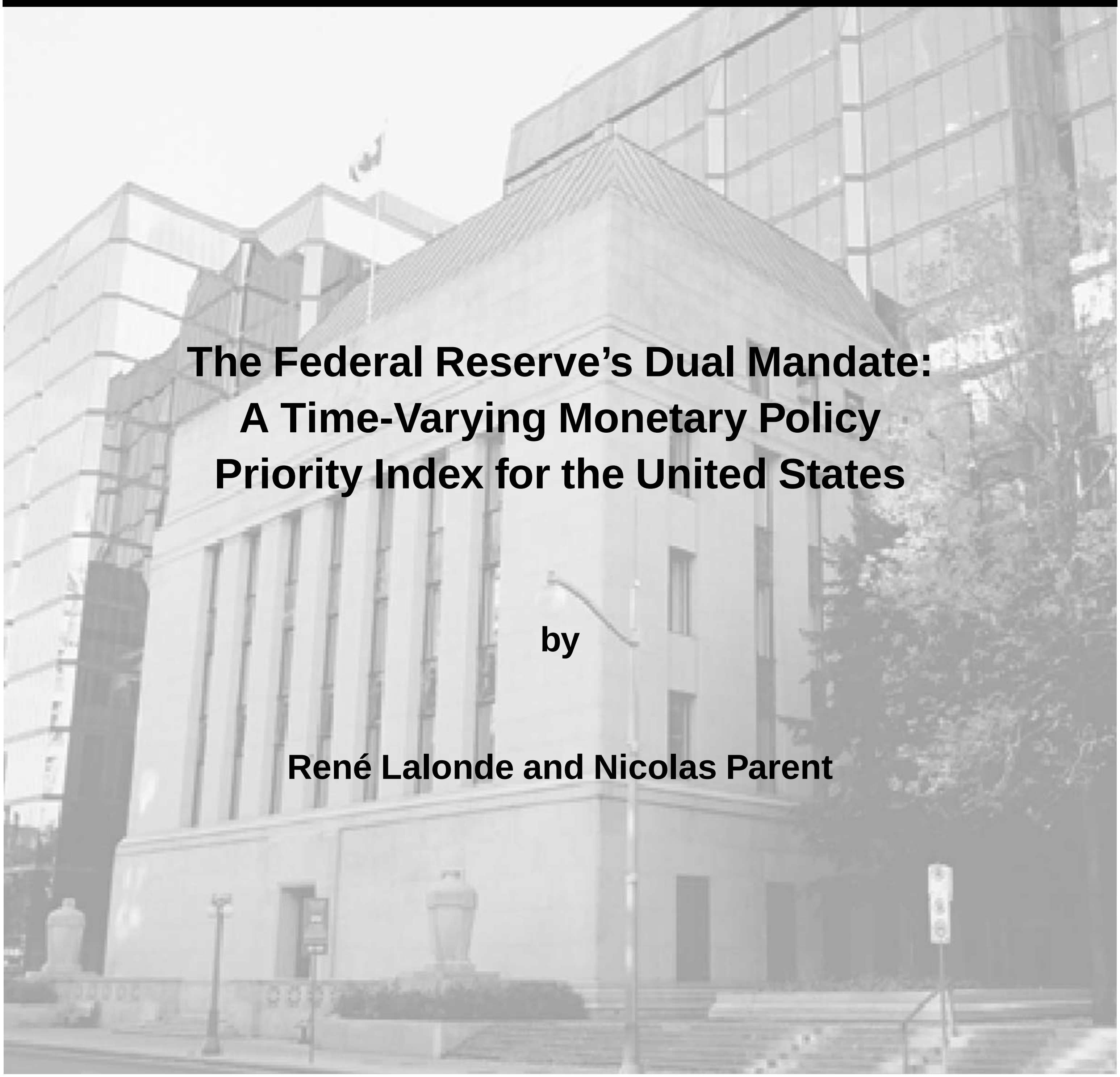

The Federal Reserve's Dual Mandate: A Time-Varying Monetary Policy Priority Index for the United States

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Abstract

In the United States, the Federal Reserve has a dual mandate of promoting stable inflation and maximum employment. Since the Fed directly controls only one instrument—the federal funds rate—the authors argue that the Fed's priorities continuously alternate between inflation and economic activity. In this paper, the authors assume that the effective weights put by the Fed on different indicators vary over time. To test this assumption, they estimate a monetary policy priority index by adding non-linear endogenous weights to a conventional Taylor-type rule.

In a departure from the existing literature, the authors do not try to distinguish between long-lasting monetary policy regimes. Instead, their model allows the Fed's priorities to vary continuously. It is therefore possible to assess the Fed's priorities at any given time during the Greenspan era. Further, the authors' non-linear reaction function specification allows the Fed to react more agressively to inflation the more expected inflation diverges from an implicit target. The specification takes into account the accepted idea that the Fed's inflation mandate ultimately prevails over its economic activity mandate.

The authors' results are intuitive and corroborated by historical evidence. Indeed, the monetary policy indexes show that the Fed's focus was mainly on inflation over the first 10 years of Greenspan's term as Fed chairman. Then, around 1998, economic activity became the Fed's main focus. This is consistent with the gain in the Fed's credibility over the Greenspan era.

JEL classification: C22, C52, E52
Bank classification: Monetary policy framework; Monetary policy implementation; Econometric and statistical methods

Résumé

Aux États-Unis, la Réserve fédérale a le double mandat de promouvoir la stabilité de l'inflation et un niveau d'emploi maximal. Comme elle ne contrôle directement qu'un instrument — le taux des fonds fédéraux —, les auteurs soutiennent que ses priorités oscillent constamment entre deux pôles : l'inflation et l'activité économique. Ils postulent en conséquence que l'importance relative effectivement accordée par la Réserve fédérale aux différents indicateurs varie au fil du temps. Pour tester cette hypothèse, ils estiment un indice des priorités de la politique monétaire en intégrant à une règle de Taylor classique des pondérations endogènes non linéaires.

Rompant avec la pratique de leurs prédécesseurs, les auteurs ne cherchent pas à dégager les orientations de la politique monétaire à long terme, mais formulent un modèle dans lequel les priorités de la Réserve fédérale peuvent varier de façon continue. De la sorte, il devient possible d'évaluer à tout moment ce qu'ont été les priorités de l'institution sous la houlette de Greenspan. En outre, la fonction de réaction non linéaire retenue par les auteurs permet à la Réserve fédérale de réagir à l'inflation avec d'autant plus de force que le taux d'inflation attendu s'écarte d'une cible implicite. Sa forme traduit l'idée admise que la lutte contre l'inflation prime en fin de compte sur la promotion de l'activité économique dans le double mandat de l'institution.

Les résultats obtenus sont intuitifs et corroborés par les données historiques. Comme le montre bien l'indice des priorités mis au point, la Réserve fédérale s'est surtout préoccupée de l'inflation durant la première décennie de la présidence de Greenspan, puis elle a tourné davantage son attention vers l'activité économique aux alentours de 1998. Cette évolution concorde avec l'amélioration de la crédibilité de l'institution durant l'ère Greenspan.

Classification JEL : C22, C52, E52
Classification de la Banque : Cadre de la politique monétaire; Mise en œuvre de la politique monétaire; Méthodes économétriques et statistiques

1. Introduction

Economists and financial analysts are interested in estimating the reaction function (the central bank's response to economic developments), since it allows them to forecast policy decisions on the interest rate, estimate forward-looking macro models, and evaluate policy actions. Estimating a reaction function over history can also reveal the weights that a central bank put on a given objective when taking policy actions during a given period. In this paper, we estimate the priorities of the U.S. Federal Reserve and their evolution through the Greenspan era.

The Federal Reserve has a dual mandate of promoting stable inflation and maximum employment. Since the Fed directly controls only one instrument—the federal funds rate—we argue that the Fed's priorities continuously alternate between inflation and economic activity. Barring adverse supply shocks, these two goals are usually not in conflict with each other, which facilitates monetary policy implementation.

In this paper, we assume that the effective weights put by the Fed on different indicators vary over time. To test this assumption, we estimate a monetary policy priority index by adding non-linear endogenous weights to a conventional Taylor-type rule. These endogenous weights vary between 0 and 1, depending on whether the Federal Reserve puts more or less weight on a given indicator. As in most Taylor-type reaction functions, inflation and the output gap are the two main indicators considered. Since the Federal Reserve Act specifically underscores the goal of full employment, we also assess whether, at certain times, the Fed focuses more on an employment gap.

In a departure from the existing literature, we do not try to distinguish between long-lasting monetary policy regimes (see, for example, Clarida, Galí, and Gertler 1998; Fair 2001; and Judd and Rudebusch 1998). Instead, our model allows the Fed's priorities to vary continuously. It is therefore possible to assess the Fed's priorities at any given time during the Greenspan era. Further, our non-linear reaction function specification allows the Federal Reserve to react more agressively to inflation the more expected inflation diverges from an implicit target. Our specification takes into account the accepted idea that the Fed's inflation mandate prevails over its economic activity mandate. Thus, we believe that, by moving away from a fixed-weight reaction function, our reaction function permits greater flexibility and may be more in line with how policy-makers actually set interest rates in the United States. We also contribute to the existing literature by empirically estimating the Fed's focus over recent history. The resulting priority index could also help forecasters to determine which indicator is currently the most relevant to predict upcoming monetary policy decisions.

Our results are intuitive and corroborated by historical evidence. Indeed, the monetary policy indexes show that the Fed's focus was mainly on inflation over the first 10 years of Greenspan's term as Fed chairman. Then, around 1998, economic activity became the Fed's main focus. This is consistent with the increase in the Fed's credibility over the Greenspan era.

2. Literature Review

The Federal Reserve Act specifies that the Federal Reserve System and the Federal Open Market Committee (FOMC) should seek "to promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates."[1] As the Fed recognizes, however, some tension can exist in the short run between efforts to reduce inflation and efforts to maximize employment and output. For instance, a significant increase in oil prices would require opposite monetary policy responses to support employment and to reduce inflation.

Taylor (1993) suggests a very simple rule for monetary policy. In this rule, the nominal federal funds rate responds to the equilibrium funds rate as well as the contemporaneous inflation gap and output gap. The equilibrium funds rate is the interest rate at which demand and supply are equal in the long run and inflation is stable. While the output gap

[1] The Humphrey-Hawkins Act of 1978 affirms that the responsibility of the federal government is to promote "full employment and production . . . and reasonable price stability," among other things.

signals how far from full capacity the economy stands, it also adds a forward-looking dimension to the Taylor rule, since it is a good predictor of future inflation. According to Judd and Rudebusch (1998), Taylor-type rules are "consistent with a policy regime in which the Fed attempts to control inflation in the long run and to smooth the amplitude of the business cycle in the short run." Taylor (1993) does not estimate this policy rule. He imposes a weight of 1.5 on the inflation gap and 0.5 on the output gap.[2] Nevertheless, Taylor shows that this simple interest rate rule fits the data during the period 1987 to 1992 reasonably well.

Given the significant lags present in the transmission mechanism for monetary policy, an explicit forward-looking rule is more appropriate than a reaction function based on the contemporaneous inflation gap. Clarida, Galí, and Gertler (1998) claim that a forward-looking rule should be a better fit for U.S. monetary policy, since it is consistent with how Fed policy-makers themselves describe monetary policy, as shown by the following remarks by Greenspan in 1997:

> . . . current conditions should not be seen as a basis for monetary policy, only as an indicator of whether inflationary pressures might be starting to build. . . . What the Federal Reserve will have to judge is not so much the question of where prices are or have been, but rather what is the state of the economy later this year and into 1998 when any actions we may or may not have taken would become effective. (Stevenson 1997)

There are different ways to estimate an explicit forward-looking Taylor rule and account directly for the expected inflation. Côté et al. (2002) note, for example, that it is possible to include the forecast values for inflation that are taken from an economic model, or to use current values of variables that are believed to be good indicators of future inflation. In this paper, we choose to use the results of surveys on expected inflation.

While most interest rate rules in the literature use some measure of the output gap, other indicators of economic activity can be used. For example, Fair (2001) uses the

[2] To achieve price stability, Taylor demonstrates that the inflation-gap coefficient should be greater than one.

unemployment rate and the change in the unemployment rate, and finds that they have additional explanatory power. He concludes that the unemployment rate may be a better variable than the output gap in a reaction function. It is therefore interesting to test whether, at different times in the business cycle, the Fed focuses more on the output gap (a very broad measure of economic activity) or the labour market.

Overall, it appears that there have not been any great successes in modelling Fed behaviour with a single, stable reaction function. There are many reasons why a reaction function cannot explain policy actions over a very long period. Judd and Rudebusch (1998) note that a central bank reaction function may be too complex to be adequately captured by a simple linear regression. Changes in the composition of the FOMC can also modify the specification of a reaction function.

As Hetzel (2000) explains, economists generally use the year 1980 as a dividing line between policies that failed to stabilize inflation and those that succeeded. Indeed, Clarida, Galí, and Gertler (1998) estimate reaction functions over different times and conclude that interest rate policies in the Volcker-Greenspan era appear to have been much more sensitive to changes in expected inflation than in the pre-Volcker era. Various authors, however, refute such conclusions. One of the problems, according to Chang, Swamy, and Tavlas (2003), is that this methodology assumes that the dates at which the parameters of the fixed-coefficient have changed are known with certainty.

Several studies also question the assumptions that the relationship between the interest rate and its determinants is linear and that the coefficients in this relationship are fixed. For instance, Chang, Swamy, and Tavlas (2003) believe that:

> . . . it would seem reasonable to allow for the possibility that the central bank adjusts the interest rate it controls more rapidly to a given gap between actual or expected inflation, and to the gap between actual and potential output, in light of the existing cyclical situation.

2.1 Non-linear reaction function

Linear reaction functions are based on the assumption that the central bank has a quadratic loss function and that the Phillips curve is linear. Recent studies challenge both of these assumptions. Orphanides and Wilcox (1996) abandon the assumption of a quadratic loss function and develop a theoretical model in which the weights given to inflation and output stabilization are not independent. In this framework, the central bank puts more weight on stabilizing output when inflation is low, but more weight on inflation whenever inflation exceeds a certain threshold level.

Kim, Osborn, and Sensier (2005) investigate the nature of any non-linearities in the central bank's reaction function using a methodology developed by Hamilton (2001). They find no evidence of non-linearity in U.S. monetary policy when data covering the period 1960–2000 are used. They find relatively strong evidence of non-linearity for the pre-Volcker era, but no such evidence for the Volcker-Greenspan era. For the pre-Volcker era, their results are consistent with recession aversion, in which policy-makers care more about decreases than increases in output. These results are in line with those obtained by Gerlach (2000). The Fed seems, however, more reactive to inflation deviations above target than below target.

Bec, Ben Salem, and Collard (2002) test for the presence of asymmetries in the monetary policy reaction function with respect to inflation and output targets. They explore the possibility that the central bank reaction function depends on the state of the business cycle measured by the output gap. Their results are consistent with an endogenously determined reaction function specification. The Fed seems to be more aggressive regarding an inflation gap during expansions than during recessions.

In this paper, instead of testing parameter stability between successive FOMC chairman mandates, we focus only on the Greenspan era to estimate monetary policy priority indexes. In this way, even if the Fed's focus is allowed to alternate between different indicators, our assumption that most parameters are stable over the sample period is more plausible. To estimate the priority indexes, we use a non-linear reaction function in which the effective weights associated with the determinants are time-varying and endogenously determined. Contrary to Bec, Ben Salem, and Collard (2002), we assume that the central bank reaction function depends on the deviations of inflation from its targeted value, rather than on the output gap. This is broadly in line with the theoretical model developed by Orphanides and Wilcox (1996), since the Fed will put more weight on inflation when the deviations from the target are larger. However, while the Orphanides and Wilcox model is based on a certain inflation threshold (a function of the policy-maker's preferences), our reaction function allows the weight on inflation to increase with the inflation gap in a continuous manner.

3. Methodology

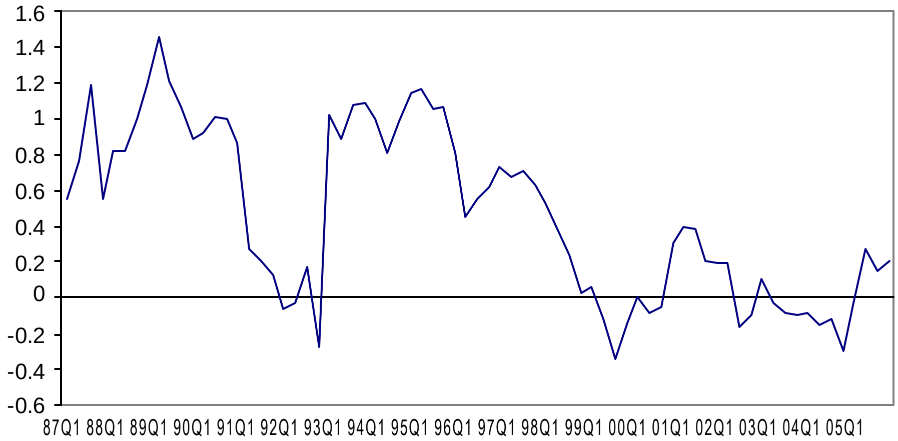
We first assume a forward-looking reaction function that follows a simple Taylor-type rule. In this specification, the monetary authority can react to both an indicator of economic activity (in this case, either the output gap (*y_gap*) or the employment gap (*emp_gap*)) and the expected inflation gap (*inf_gap*) (see equation (1)).[3,4] The inflation target is from Lalonde (2005), who identifies one historical shift over the period we consider.[5] Figure 1 shows the evolution of the expected inflation gap (the difference between expected inflation, based on surveys done by the Federal Reserve Bank of Philadelphia, and the inflation target) over the Greenspan era. According to this inflation-gap measure, inflation expectations have been well anchored around the inflation target only since the late 1990s.

[3] The output gap used is derived from the methodology of Gosselin and Lalonde (2002). Their approach consists of Hodrick-Prescott (HP) filters to which an equilibrium path generated by a structural vector autoregression (SVAR) is added as information conditioning the filter. The methodology used to calculate the equilibrium level of employment (necessary to derive the employment gap) is based on the same approach that combines an SVAR and an HP filter. Details are given in Appendix A.

[4] Our inflation measure is based on the GDP deflator. The inflation gap is the gap between inflation expected in the next four quarters (as captured in the survey done by the Federal Reserve Bank of Philadelphia—Survey of Professional Forecasters) and the target. This is similar to a year-over-year measure of inflation and therefore is less volatile than the annualized rate of change between two subsequent quarters.

[5] Lalonde (2005) uses a Bai-Perron test for endogenous structural breaks and identifies one break in 1992Q4 in the core consumption deflator.

Figure 1: The Expected Inflation Gap



Our base-case reaction function is:

$$i_t = a + l_1 \cdot i_{t-1} + l_2 \cdot i_{t-2} + b_1 \cdot inf\_gap_{t+4} + b_2 \cdot y\_gap_t, \qquad (1)$$

where i_t is the nominal federal funds rate in period t and inf_gap_{t+4} represents the average of the expected inflation gap over the next four quarters. Following the literature, the policy rule is consistent with the Federal Reserve's preference for interest rate smoothing.[6] The nominal federal funds rate gradually converges to the Taylor-rule prescription.

In the above reaction function, the weights attributed to each gap are fixed. As with Chang, Swamy, and Tavlas (2003), we believe that this assumption is too strong, even if we consider a short period of time. In reality, the Fed's priorities are probably highly dependent on economic circumstances. A reaction function could therefore allow the weight attributed to the output gap and the inflation gap to vary over time. To account for a varying weight, we add a time-varying monetary policy priority index to the rule.

[6] The literature provides different explanations for the preference for interest rate smoothing (see Srour 2001), including the high degree of uncertainty around economic forecasts and the impact of interest rate decisions. Goodfriend (1991) discusses central banks' fears of disrupting financial markets.

Therefore, we modify the base-case Taylor rule (equation (1)) to include the time-varying weights y_t and 1-y_t on the output gap and the inflation gap. Thus, at any given time, the Fed can decide to prioritize one of its two mandates (price stability versus full employment). The new reaction function is as follows:

$$i_t = a + l_1 \cdot i_{t-1} + l_2 \cdot i_{t-2} + (1 - y_t) \cdot b_1 \cdot inf\_gap_{t+4} + (y_t) \cdot b_2 \cdot y\_gap_t . \qquad (2)$$

In light of recent history and Fed communication,[7] we assume that price stability is the Federal Reserve's ultimate goal, and that it will therefore examine the deviation of the expected inflation from the inflation target in order to determine the weight it places on this indicator.[8] As a result, the expected inflation gap is the decision variable. The further expected inflation is from the target, the greater the weight will be on the inflation gap (1-y = 1). Alternatively, if expected inflation is right on target, the Fed will put no weight on the inflation gap and all the weight on the output gap (y = 1).

The monetary policy priority index is modelled as follows:

$$y_t = e^{\frac{-mave(inf\_gap_{t+3})^2}{2q_1^2}} . \qquad (3)$$

The priority index, y is distributed between 0 and 1, and follows a standardized normal functional form. This specification carries two main properties. First, the priority index is non-linear, so that small deviations have less of an impact on the index relative to larger ones. This is consistent with the Fed being able to tolerate small deviations from target, given its preference for smooth interest rate movements, and being able to account for possible measurement errors. Also, since higher deviations are likely to lead to some credibility loss, it is logical for the Fed to react in a non-linear way to deviations from the

[7] See "Federal Reserve System Purposes and Functions: Monetary Policy and the Economy," on the Fed's website at <http://www.federalreserve.gov/pf/pf.htm>.

[8] We use an eight-period moving average (mave) of the inflation gap. This way, Fed priorities will not change from inflation to economic activity (and vice versa) based on temporary movements in inflation.

inflation target. Second, the priority index is symmetric. We therefore expect the Fed to adopt a similar strategy whether deviations from the target are positive or negative.

Equation (3) shows that the priority index depends on the estimated coefficient, q_1. This is a key coefficient: it determines, for any given deviation from the target, the speed at which the Fed will reorient its priority from economic activity towards inflation. The smaller the q_1, the greater the average weight will be on the expected inflation gap for a given period. Thus, q_1 is inversely proportional to the Fed's bias towards inflation. To illustrate the impact of q_1, Figure 2 shows the weights attributed to the expected inflation gap for any deviation from the inflation target if q_1 = 0.003 and if q_1 = 0.006.

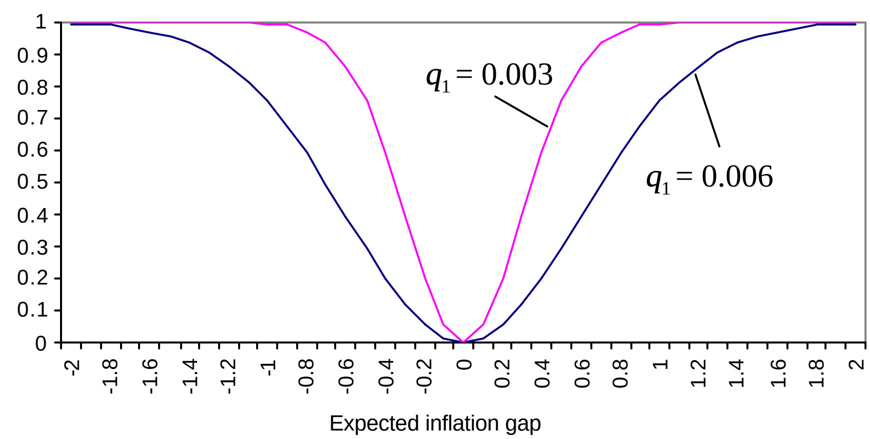


Figure 2: Priority Index and the Gap Between Inflation Expectations and the Target

In light of the previous example, consider the extreme case where q_1 is very small. In this situation, the Fed would not tolerate any deviations of expected inflation from the target. Thus, $1-y$ will almost always be equal to 1, and most, if not all, monetary policy decisions will be driven by the expected inflation gap. In this case, the output gap would be pertinent to monetary policy only when the expected inflation rate is on target.

Given equations (2) and (3), we use the following specification for the reaction function that includes the priority index:

$$i_t = a + l_1 \cdot i_{t-1} + l_2 \cdot i_{t-2} + b_1 \left[1 - e^{\left(-mave(inf\_gap_{t+3})^2 / 2q_1^2 \right)} \right] \cdot inf\_gap_{t+4} + b_2 \left[e^{\left(-mave(inf\_gap_{t+3})^2 / 2q_1^2 \right)} \right] \cdot y\_gap_t . \tag{4}$$

As with most Taylor rules, the output gap captures economic activity.[9] Depending on the circumstances, however, it is possible for the Fed to focus on other indicators of economic activity. For example, since full employment is part of the Fed's mandate, we believe that, on certain occasions, the Fed may have focused mainly on the labour market in making its policy decisions. Consider that, in 2003, U.S. economic growth appeared to be above its potential for several quarters, yet the Fed left interest rates at their historical low of 1 per cent until June 2004. Most analysts note that job creation was anemic over this period, despite the sustained economic growth. The Fed probably waited for some strengthening in the labour market before it started to raise rates.

To take this assumption into account, we estimate a second reaction function in which, on top of the trade-off between inflation and economic activity, we let the Fed make either the output gap or the employment gap its priority. This should allow us to determine the weights that the Fed puts on these two indicators of economic activity. In this specification, there are two monetary policy priority indexes:

$$y_{1t} = e^{\frac{-mave(inf\_gap_{t+3})^2}{2q_1^2}} , \tag{5}$$

and

$$y_{2t} = e^{\frac{-mave(emp\_gap_{t-1})^2}{2q_2^2}} . \tag{6}$$

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[9] Most researchers recognize, however, that the output gap suffers from different measurement problems (see, for example, Hetzel 2000).

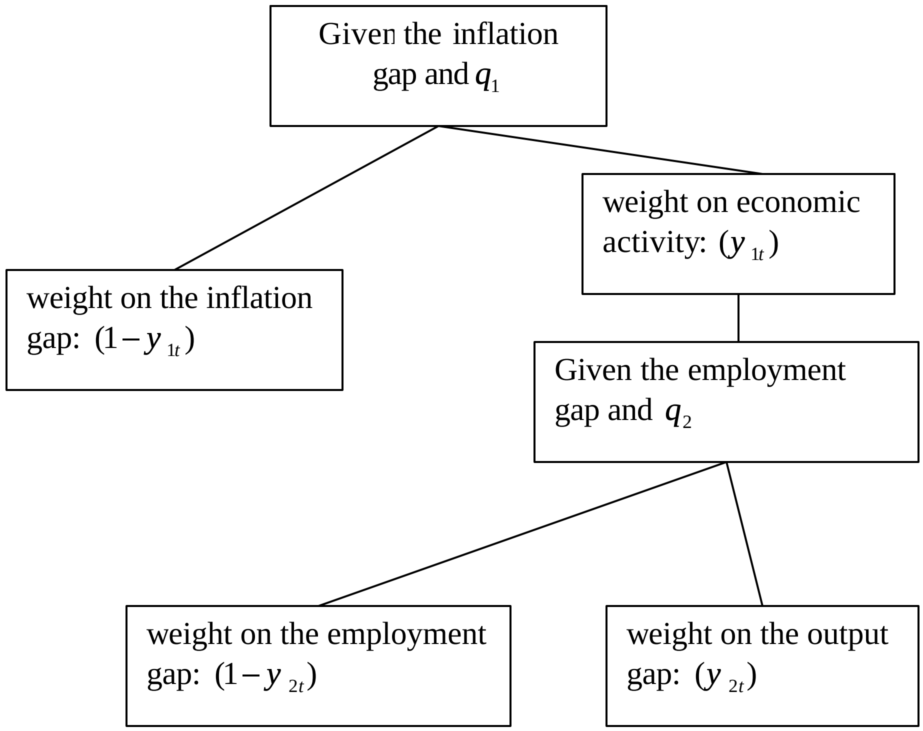
The inflation gap is the decision variable in the first priority index (see equation (5)). In this specification, however, the second priority index (y_{2t}) allows the Fed to alternate priorities between the employment gap and the output gap (see equation (6)). In this case, we assume that the decision variable is the employment gap, since employment is directly referred to in the Federal Reserve Act. Also, this indicator may be more reliable, because employment is easier to measure than output. In this case, q_2 is the key coefficient: it determines, for any given deviation of employment from its equilibrium level, the speed at which the Fed will reorient its priority from the output gap towards the employment gap. The smaller the q_2, the greater the average weight will be on the employment gap for a given period. q_2 is thus inversely proportional to the Fed's bias for the labour market.

The varying weight between the output gap and the employment gap is also distributed between 0 and 1 following a normal functional form. q can, however, differ for the two sets of time-varying weights. We thus have:

$$i_t = a + l_1 \cdot i_{t-1} + l_2 \cdot i_{t-2} + b_1 \cdot [1 - y_{1t}] \cdot inf\_gap_{t+4} + y_{1t} \cdot [b_2 \cdot [1 - y_{2t}] \cdot emp\_gap_t + b_3 \cdot y_{2t} \cdot y\_gap_t]. \quad (7)$$

To provide a better idea of what this reaction function implies, Figure 3 illustrates the Fed decision process.

Figure 3: The Federal Reserve Decision Process



First, the Fed considers the expected inflation gap and, given q_1 (its bias towards inflation), attributes a weight to the expected inflation gap and economic activity. The Fed then observes the employment gap and, given q_2 (its bias towards maximum employment), attributes a weight to the employment gap and the output gap. Note that this is a simplification; in reality, everything is estimated simultaneously.

4. Estimation Procedures

We use two different approaches to estimate the non-linear Taylor-type rules. First, we estimate the reaction functions with non-linear least squares using the generalized method of moments (GMM) to address potential simultaneity bias (the federal funds rate responds to output and expected inflation, but also affects these variables).[10] Second, to test for the robustness of the results, we use a grid search as an alternative method of

[10] Our instrument sets for the GMM include a constant and four lags of the following variables: nominal federal funds rate, inflation, the inflation gap, and the output gap.

estimation. Given the specification of the reaction function, q cannot be equal to zero. Thus, we use the grid search to find the value of q that minimizes the root mean squared errors (RMSE) of the regressions. Specifically, we impose values for q (starting with values very close to zero), estimate the reaction functions for each q, and select the one that minimizes the RMSE.

5. Results

For comparison purposes, we first estimate equation (1), the linear Taylor-type rule with a fixed weight (Table 1, case A). Parameters a, l_1, l_2, b_1, and b_2 are estimated. In the base-case reaction function, all the coefficients have the expected sign and are significant. As found in the literature, the coefficient on inflation is significantly higher (about three times the size) than the coefficient associated with the output gap. The sum of the two smoothing parameters equals 0.91, which shows that the Federal Reserve has a strong preference for interest rate smoothing.

Table 1: Estimation Results (1987Q3 to 2004Q4)

	Estimation procedure	a	l_1	l_2	b_1	b_2	q_1	RMSE
A	Equation (1): (by GMM)	0.0028	1.356	-0.451	0.375	0.096		0.00297
		(6.99)	(28.85)	(-10.20)	(7.37)	(5.52)		
B	Equation (4): (by GMM)	0.0045	1.259	-0.400	0.578	0.223	0.0029	0.00296
		(8.01)	(18.06)	(-6.79)	(5.37)	(5.06)	(5.50)	
C	Equation (4): (no GMM)	0.0039	1.286	-0.419	0.609	0.189	0.0027	0.00293
		(4.22)	(13.07)	(-4.85)	(4.80)	(4.50)	(4.53)	
D	Equation (4): (grid search and GMM)	0.0045	1.262	-0.402	0.580	0.216	0.0030	0.00295
		(8.12)	(18.69)	(-7.16)	(5.74)	(6.21)		
E	Equation (4): (grid search no GMM)	0.0039	1.286	-0.419	0.609	0.189	0.0027	0.00293
		(4.23)	(12.98)	(-4.82)	(4.70)	(4.57)		

Note: The *t*-statistics are shown in parentheses.

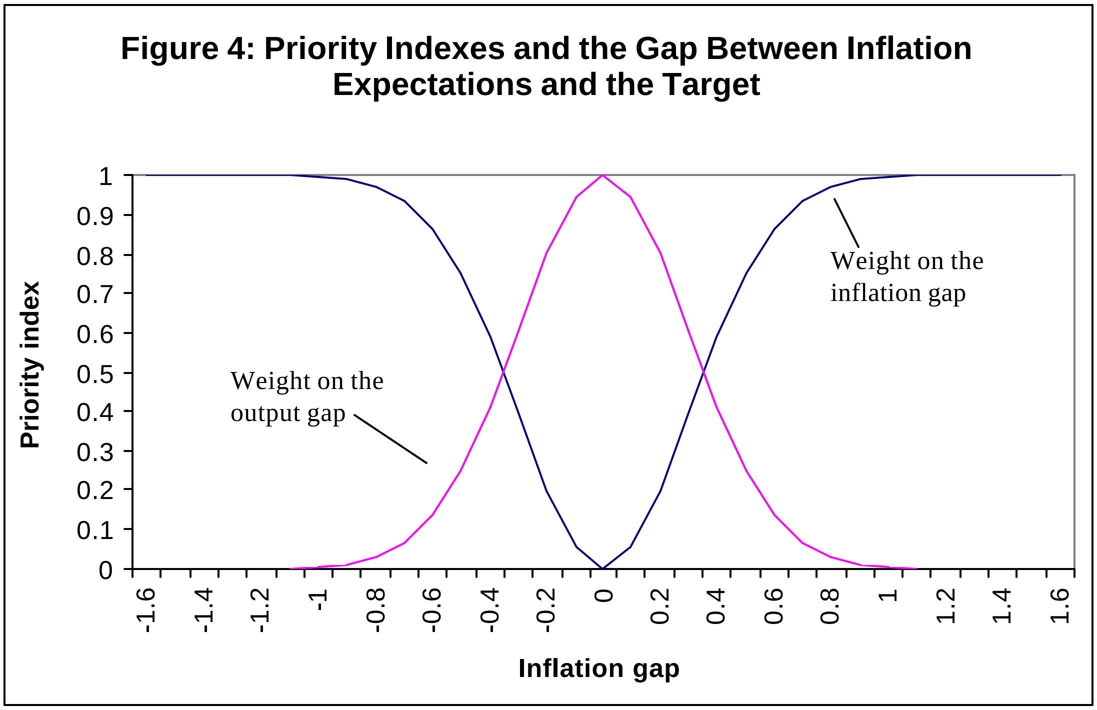
Equation (4) includes the monetary policy priority indexes that allow the Fed to alternate its priority between the expected inflation gap and the output gap. Parameters a, l_1, l_2, $b_{1,}$ b_2, and q_1 are estimated. Table 1 (cases B, C, D, and E) shows the results of equation (4) based on the different estimation procedures.[11] In all cases, while a, l_1, and l_2 remain roughly in line with the results from equation (1), the coefficients on the expected inflation gap and the output gap have both increased significantly. Indeed, the coefficient associated with inflation almost doubles in size when the priority index is taken into account. This is expected, since both parameters are multiplied by the priority indexes, which vary between 0 and 1.

We will use the results from case D estimated with GMM, since the grid search improves the fit relative to the simple non-linear least squares. To be able to compare the coefficient from equation (1) with those from equation (4), we calculate the average "effective" coefficient for inflation $((1-y_t)\cdot b_1)$ and for the output gap $(y_{t\cdot} \cdot b_2)$. These effective coefficients are, respectively, 0.418 (compared with 0.375 in equation (1)) and 0.06 (compared with 0.096 in equation (1)). Over the whole sample, it seems that the Fed might have, on average, put more weight on the inflation gap than what is normally assumed when estimating the fixed-weight reaction function. However, the difference in the estimated coefficient is not very large.

The coefficient associated with the monetary policy priority index (q_1) is statistically significant, being around 0.0030 (although we estimate q_1 using a grid search, we can deduce that the coefficient is significant because we get nearly the same result for q_1 even without using the grid search, as shown in Case B). Figure 4 illustrates how the monetary policy priority index varies with the expected inflation gap when q_1 equals 0.0030. Our estimates show that, as long as deviations of inflation expectations from target are less than 0.4 percentage points, the Fed will put more weight on the output gap than on the inflation gap. When expected inflation deviates persistently from its target by

[11] It is important to note that none of the coefficients is very sensitive to the use of GMM.

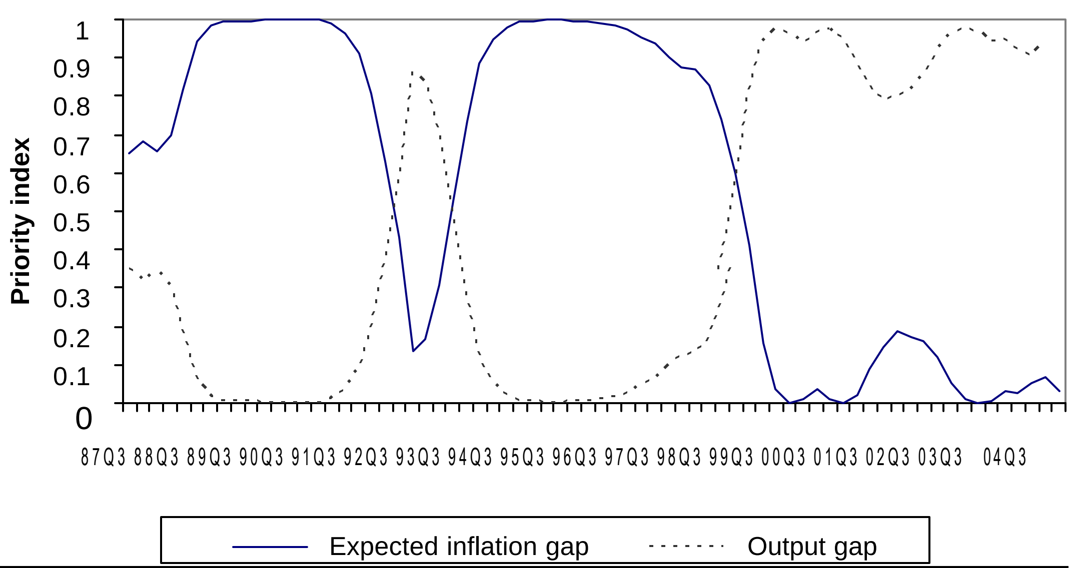
more than a full percentage point, however, the weight on inflation approaches 1. On those occasions, the Fed will focus almost exclusively on the expected inflation gap when making monetary policy decisions.



These results are intuitive and corroborated by historical evidence. Keep in mind that our inflation measure is based on the GDP deflator, which is more volatile than core measures of inflation. Given the volatility of this measure, the Fed does not react to high-frequency movements. Therefore, the Fed would possibly have a lower tolerance for deviations of core measures of inflation, such as the core CPI or the price index for core personal consumption expenditures. On the other hand, we use an eight-period moving average of the inflation gap to reduce its volatility. The coefficient q_1 could be affected by this, since a smoother expected inflation gap should correspond to a smaller q_1. We re-estimate the equation with a more volatile four-period moving average of the inflation gap. As a result, q_1 increases from 0.0030 to 0.0033.

Figure 5 shows how the weight on the expected inflation gap and the output gap fluctuated over the past 15 years based on equation (4). The Fed seems to have put much more weight on inflation in the first 10 years of the Greenspan era. Then, around 1998, inflation seems to have become less of a concern for the Fed. The output gap seems to have been the main determinant of monetary policy over the past five years. This result does not imply that inflation is not a concern for the Fed, since the output gap remains a leading indicator of inflation. Moreover, under this framework, the Fed will put more weight on the output gap only when inflation seems to be under control.

Figure 5: The Priority Indexes (Greenspan era)



The behaviour of the monetary policy indexes is intuitive. At the beginning of the Greenspan era, inflation expectations were significantly higher than the observed level of inflation and the target (Figure 1). Therefore, the interest rate level was set to increase Fed credibility and bring inflation expectations closer to the target. This is consistent with the results of Lalonde (2005), who finds empirical evidence that credibility increased significantly over the Greenspan era. In fact, according to Lalonde's results, from 1987Q3–1996Q4 to 1997Q1–2003Q4, credibility increased by 25 per cent. Figure 5 also shows that, immediately following the 1990–91 recession, the Fed's focus on the output gap increased temporarily. This situation lasted until mid-1993, when the Fed's priorities moved back to inflation.[12] This behaviour is consistent with the Fed's dual mandate. Since 1999, inflation expectations have stabilized and become well anchored around the target. As expected, the priority indexes show that, over the more recent period, the Fed focused mostly on the output gap. This implies that the deviation of inflation expectations from the target were sufficiently small and short-lived to be ignored by the Fed.

Over the recent period (mostly in 2004), the financial community raised concerns about the risk of possible deflation. It could therefore seem surprising to see that the Fed's focus remained constantly on the output gap over that period. One should not interpret this result as a signal that inflation has not mattered over the recent period. Given that the output gap and the employment gap are good predictors of future inflation, the fact that the Federal Reserve left rates unchanged at 1 per cent to support output growth is not inconsistent with the fear of deflation. This suggests that the Fed does not target inflation per se, but does what it takes to close the output gap and make sure that inflation expectations do not fall significantly below the implicit target.

5.1 The employment gap

The Federal Reserve Act specifically notes the goal of maximum employment. We wish to test whether, on certain occasions, the Federal Reserve directly targets employment. To perform this test, an employment gap is included in the reaction function (equation (7)).[13] In this specification, the Fed can decide to focus on the expected inflation gap, the output gap, or the employment gap.

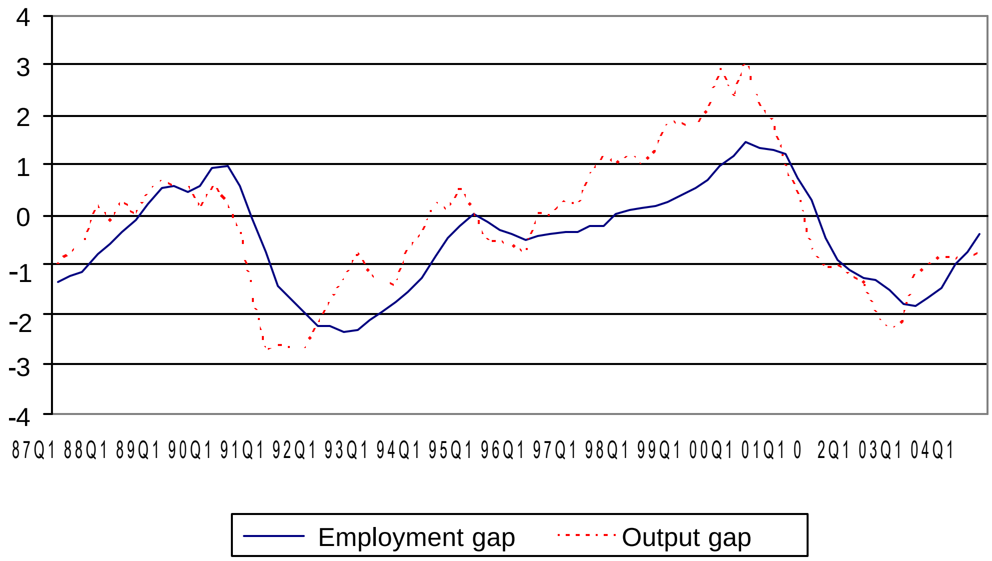
We base our employment gap on non-farm employment, using the monthly survey of the payroll records of business establishments (from the Bureau of Labor

[12] The dramatic change in Fed priorities over this period is partly due to the choice of a discrete change in the inflation target in 1992Q4. If we allow the inflation target to change in a more gradual manner, however, the change in Fed priorities remains and is only marginally smoother.

[13] Appendix A describes the methodology used to derive the equilibrium level of employment.

Statistics). Figure 6 shows how the employment gap and the output gap evolved over the Greenspan era.

Figure 6: Employment Gap and Output Gap over the Greenspan Era



As expected, these two indicators follow each other closely. This result implies that most fluctuations in the output gap are driven by fluctuations in the labour input. To verify whether the Federal Reserve can rely on either of these two measures, we re-estimate equation (4) by replacing the output gap with the employment gap. As Table 2 demonstrates, the results are comparable, implying that the Fed would derive a similar message from either indicator. The RMSE is, however, slightly lower in the case of the output gap. This result is expected, since it is a broader measure of economic activity.

Table 2: Output Gap vs. Employment Gap (1987Q3 to 2004Q4)

	a	l_1	l_2	b_1	b_2	q_1	RMSE
Equation (4) (output gap)	0.0045	1.262	-0.402	0.580	0.216	0.0030	0.00295
	(8.12)	(18.69)	(-7.16)	(5.74)	(6.21)		
Equation (4) (employment gap)	0.0028	1.485	-0.567	0.272	0.109	0.0022	0.00316
	(3.20)	(24.29)	(-11.16)	(4.56)	(1.71)		

Figure 6 shows that the employment gap lags the output gap and is somewhat less volatile. Further, some periods show more divergence between the two indicators. In the late 1990s, for example, the increase in the output gap was not followed by a proportional increase in the employment gap. This highlights the fact that economic growth over this period was supported mostly by an increase in the labour-productivity gap. But is there enough complementary information in these two measures of economic activity to make the Fed want to focus on both measures? To answer this question, we estimate equation (7), in which there is a trade-off between inflation and economic activity, and a second trade-off between the two measures of economic activity.

In equation (7), parameters $a, l_1, l_2, b_1, b_2, b_3, q_1$, and q_2 are estimated. Table 3 reports the results. Interestingly, whichever estimation procedure is used, the coefficient of the employment gap (i.e., b_3) is never significant. We therefore conclude that, while the Fed can focus on either measure of economic activity, the employment gap does not add any new information.

Table 3: Output Gap and Employment Gap (1987Q3 to 2004Q4)

	a	l_1	l_2	b_1	b_2	b_3	q_1	q_2	RMSE
Equation (7) (no GMM)	0.0027	1.256	-0.375	0.648	0.276	0.001	0.0027	0.013	0.00290
	(2.16)	(12.74)	(-4.44)	(4.94)	(0.01)	(0.01)	(4.11)	(2.06)	

6. Robustness Analysis

As a final step, we conduct several robustness tests to make sure that our results are not too sensitive to some base-case assumptions. First, the assumption of a constant neutral interest rate may be too strong. In theory, the equilibrium short-term interest rate varies, being influenced by, for example, productivity and inflation expectations. To test whether our results are sensitive to the assumption of a constant neutral interest rate, we re-estimate equation (4) by imposing a time-varying neutral interest rate, which is derived from an HP filter applied to the historical nominal federal funds rate. Our results are robust to this change. Moreover, the importance of the smoothing parameter in the HP filter does not change the priority index, and therefore the conclusions remain unchanged.

The second robustness test that we perform aims to confront the fixed-weight specification (equation (1)) against the time-varying weight specification. To do so, we try to estimate a version of equation (4) where the weight on the output gap is specified as follows:

$$b_2\left[z + e^{\left(-mave(inf\_gap_{t+3})^2 / 2q_1^2\right)}\right].$$

In this specification, we allow for the same time-varying weight as in equation (4), but we also allow for a fixed weight (i.e., $b_2 \cdot z$) on the output gap. This version of equation (4) incorporates equation (1), because if the coefficient q_1 is close to 0, the weight on the inflation becomes $b_1[1-0]$, which is the equivalent of a fixed weight, and the weight on the output gap is also fixed (i.e., $b_2[z+0]$). We use a grid search to select which combination of b_2 and z minimizes the RMSE, estimating the other parameters for every combination. This new version of equation (4) is difficult to estimate. In fact, we do not have any success using GMM, but the non-linear least-squares estimation shows that q_1 is statistically significant and equal to 0.0026 (compared with 0.0030 for equation (4)). Furthermore, the fixed weight $b_2 \cdot z$ on the output gap is very small (i.e., 0.02) and statistically insignificant, because z is statistically no different than 0. Finally, b_2 is equal to 0.18 (compared with 0.189 for equation (4)) and statistically significant. These results give some indication that variable weights could be preferable to fixed weights, but further work needs to be done on this issue.

Finally, we test whether our results are sensitive to the sample period, by increasing the sample to include the last five years of the Volcker era (making the sample period thereby span from 1983Q1 to 2004Q4).[14] The priority index shows that, from 1983 to 1986, the Federal Reserve put almost all the weight on inflation. This result is intuitive. Over the Greenspan era, the priority index evolves almost exactly the way it does when estimated over the shorter sample.

7. Conclusion

Most studies that are interested in parameter stability in Taylor-type rules try to distinguish between long-lasting monetary policy regimes that are defined by the terms of Fed chairmen. Our base assumption is that the weights put on different indicators by the Fed depend on economic circumstances and should therefore vary even within a chairman's mandate. As a result, in this paper we estimate monetary policy priority indexes that capture the Fed's main priorities when they make monetary policy decisions.

Our results from the reaction function in which non-linear endogenous weights are included confirm our expectations. Over the first 10 years of the Greenspan era, the Fed's focus was mainly on inflation. Over that period, inflation expectations were not well anchored. To build credibility, the Federal Reserve had to be more aggressive with regards to inflation. Since the late 1990s, inflation expectations have been well anchored.

[14] 1983Q1 corresponds to a second break in the inflation target.

Therefore, as our results show, over the past five years the Fed has acted mainly to smooth the economic cycle. Our results suggest also that, although the employment gap is a good proxy for the output gap in a reaction function, it does not add new information.

Different extensions of this work are possible. First, methods other than the Bai-Perron test for endogenous structural breaks could be used to identify the historical inflation targets. Second, statistical distributions other than the normal distribution could be used for the time-varying weight in the reaction function. An asymmetrical distribution could indeed be more suitable, given that the risk of deflation possibly requires more aggressive reactions from policy-makers than a positive increase in inflation.

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Appendix A: The Employment Gap

To estimate the equilibrium level of employment, we use an extended multivariate Hodrick-Prescott filter to which an equilibrium path generated by an SVAR is added as information conditioning the estimate. This method generates an equilibrium that is smoother than that given by an SVAR while reducing end-of-sample problems inherent in filters (see Gosselin and Lalonde 2002). Using Monte Carlo simulations, Rennison (2003) shows that this approach adequately reproduces the output gap from the data-generation process (a model economy), for a wide variety of specifications of the process's parameters. The SVAR approach, based on the Blanchard and Quah (1989) decomposition, identifies trends in the variables of a VAR by imposing restrictions on the long-term impacts of structural shocks. The variable of interest (in this case, employment) should be separable into permanent and temporary components.

A.1 Specification of the SVAR

In addition to the change in the level of employment, we include four variables in the SVAR: (i) a nominal variable (the index for compensation per hour), in order to allow the model to distinguish between nominal and real variations, and therefore between supply and demand shocks; (ii) the real federal funds rate, to account for the impact of monetary policy; (iii) the real yield on 10-year government bonds, to capture other types of demand shocks; and (iv) the change in non-farm production (output), to capture the links between the economic cycle and those of employment.

This specification is very similar to, and therefore compatible with, the one used in the SVARs underlying the output gap.

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