Non Linearities in Taylor Rules - Causes, Consequences and Evidence

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1 Intoduction

The last decade has witnessed the development of an academic literature that tries to characterize and quantify monetary policy choices by central bankers or, in more technical language, to formulate and estimate the reaction function of policymakers. Following a long economic tradition such reaction functions are conceptualized as arising from an attempt by policymakers to maximize their objectives subject to a given economic structure. An early, well known illustration of this approach is the Kydland and Prescott (1977), Barro and Gordon (1983) (KPBG in the sequel) example in which policymakers possess target levels of output and of inflation and, in which, any deviation of output and of inflation from those targets is costly for them. In the KPBG framework (as well in most of the work on reaction functions till the early nineties) the relevant economic structure is based on the expectations augmented Phillips curve in which the deviation of output from its natural level is an increasing function of unexpected inflation. In those formulations central banks are assumed to directly control the rate of inflation or the money supply.

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More recent formulations in the Neo or New Keynesian tradition postulate that, due to sticky prices and wages, economic activity is demand determined within some range. Economic structure is characterized by an output gap equation and by an inflation equation. The first equation negatively relates the output gap (defined as the difference between actual and potential output) to the exante real rate of interest and the second positively relates the rate of inflation to the output gap and (in the "New" version of those models) also to expected inflation. The policy instrument of the central bank (CB) is the short term nominal rate of interest. Given inflationary expectations, the choice of this rate determines the real rate thereby affecting the output gap and inflation. Here CB losses are assumed to be increasing in the output gap and in the deviation of inflation from the inflation target (the inflation gap in the sequel). The reaction function of the CB is then derived by minimizing CB losses subject to the output gap and the Keynesian Phillips relation described above yielding the well known "Taylor rule". This rule relates the rate of interest of the CB to the output gap and to the inflation gap. In estimated versions of this reaction function a lagged interest rate term is invariably added to capture the well known tendency of central banks to change interest rates slowly and in small steps. A recent extensive treatment of Taylor rules appears in Taylor (1999).

Until very recently, practically all formulations of policymaker's loss functions, whether originating from a monetarist expectations augmented Phillips relation (PR) or from a new Keynesian framework were quadratic. A convenient feature of quadratic loss functions is that, when combined with linear economic structures, they yield linear reaction functions.[1] Quadratic loss functions also imply that policymakers are equally averse to similarly sized deviations above and below target. But recent anecdotal evidence, followed by econometric work, suggests that the quadratic specification often misses important elements of real life policymaking. In addition there is, apriori, no good reason to believe that policymakers attach the same importance to a given size deviation from target in the upward as they do in the downward.direction.

Consider, for example the output gap. Casual observations from many countries suggest that politicians and the general public are more averse to recessions (negative output gaps) than to expansions (positive output gaps). As a matter of fact, it is a bit hard to see why,

[1] In the presence of uncertainty an additional nice feature is that they yield certainty equivalence.

given inflation, they should dislike expansions at all raising the suspicion that the quadratic specification is used more for analytical convenience than for its desciptive realism. Since, in a democratic society, independent, but accountable, central banks are not totally insensitive to the wishes of the political establishement some of this asymmetry trickles down into the objective function of the CB as well. This view is consistent with the observation of a former Fed insider who wrote after leaving the Fed that "In most situations the CB will take far more political heat when it tightens preemptively to avoid higher inflation than when it eases preemptively to avoid higher unemployment" (Blinder (1998, pp. 19, 20).[2]

Similarly, during periods of inflation stabilization when the buildup of credibility is a major concern, policymakers are likely to be more averse to upward deviations of inflation from its target than to downward deviations. The disinflationary experience of the UK and Israel during the second half of the nineties provides some preliminary support to this view. During that period the inflation target in both countries was often missed from below.

These and similar observations led to the emergence, since the late nineties, of a new body of literature that incorporates the possible existence of asymmetries in the objective functions of central banks. Those formulations are sufficiently flexible to allow for the existence of precautionary demands for both expansions and for price stability. The CB is said to possess a precautionary demand for expansions when it is more averse to a negative output gap of a given absolute value than to a positive output gap possessing the same absolute value.[3] Similarly, a CB is said to have a precautionary demand for price stability if it has a stronger aversion to positive than to negative inflation gaps. Unlike quadratic objectives that, for linear economic structures lead to linear policy rules, asymmetric CB objectives lead to non linear policy rules even if the economic structure is linear. As elaborated later this provides one possible discriminatory criterion for the detection of precautionary motives on the part of the CB.

The rest of this lecture is organized as follows. Section 2 reviews two common methods for modeling asymmetric CB objectives. Section 3 explores the consequences of asymmetric employment objectives in the presence of uncertainty about future economic shocks. In particular

[2] In a survey on political economy and macroeconomic policy Persson and Tabellini, (1999) also posit a politically motivated **asymmetric** objective function (section 3).

[3] There is a strong, although not perfect, analogy between this precautionary demand and the precautionary demand for savings in the theory of consumption.

it shows that the conjunction of those two factors leads to an inflation bias even if the CB does not attempt to systematically maintain the level of output above its potential or natural level. Section 4 surveys recent empirical tests of this new type of bias as well as related empirical evidence. This is done for economic frameworks characterized by a Lucas type expectations augmented Phillips relation.

Section 5 allows for the simultaneous existence of precautionary demands for **both** expansions and for price stability using a general specification of asymmetries within a New Keynesian framework. Utilizing this framework, the section presents empirical evidence for several developed economies. Asymmetric objectives generally lead to non linear reaction functions. However, in the presence of both types of precautionary demands the reaction function may still be linear since the two types of non linearities "distort" the benchmark linear function in opposite directions. More generally a dominant precautionary demand for expansions leads to concave Taylor rules while a dominant precautionary demand for price stability leads to convex Taylor rules. This is followed by concluding remarks.

2 Modeling precautionary demands for expansions and for price stability

2.1 Asymmetric output gap objectives

Two alternative parametrizations of the precautionary demand for expansions have appeared in the recent literature. One, due to Cukierman (2000), postulates that CB losses from negative output gaps are quadratic but that, as soon as actual output becomes larger than or equal to potential output, losses are equal to zero. This hypothesis is captured formally by specifying the loss function of the CB as :

$$Af(x) + \frac{\pi^2}{2} \tag{1}$$

where

$$f(x) \equiv \begin{cases} \frac{x^2}{2} \; for \; x \leq 0 \\ 0 \; for \; x > 0. \end{cases} \tag{2}$$

and

$$x \equiv Y - Y_p \tag{3}$$

is the output gap. Here Y, Y_p and π are actual output, potential output and inflation respectively, and A is a positive parameter that characterizes the relative importance attributed by the Bank to recession avoidance versus price stability. Equation (1) states that, the CB dislikes inflation as well as negative output gaps. But, given inflation, the CB has no interest in deliberately creating positive output gaps. There are two things to note about this loss function. First, it is symmetric in inflation. Second, in the absence of uncertainty a CB possessing such a loss function is not subject to a KPBG inflationary bias.

The top panel of Figure 1 illustrates the segment $-f(x)$ of the loss function (solid line) against the quadratic benchmark (broken line). Correspondingly, the bottom panel shows the first derivative of $-f(x)$ against the first derivative of the quadratic benchmark. Note that the first derivative of this function is globally convex implying, analogously to the theory of savings under uncertainty, that this function displays a precautionary demand for expansions.[4]

The second parametrization, suggested by Ruge-Murcia (2000), provides a smoother parametrization of of the precautionary demand for expansions. It utilizes the Linex function that has been proposed and applied by Varian (1975) and Zellner (1986). Like the quadratic, this specification allows losses from the output gap to increase with the distance from zero for positive, as well as for negative, output gaps. However, for positive output gaps the rate at which losses increase with distance is smaller than the rate at which they increase with it in the negative range of output gaps. For this case the segment $f(x)$ of the loss function is

$$f(x) \equiv \frac{1}{\gamma^2} \left\{ \exp(-\gamma x) + \gamma x - 1 \right\} \tag{4}$$

where γ is a positive parameter. For negative output gaps the exponential term eventually dominates and losses rise exponentially with distance. For positive output gaps the linear term progressively becomes more important so that losses rise linearly with distance. Figure 2

[4] Kimball (1990) shows that concavity of the marginal utility of consumption is a necessary and sufficient condition for the existence of a precautionary demand for savings.

illustrates the segment $f(x)$ of the loss function for this case. Although this specification makes the somewhat unrealistc assumption that, given inflation, policymakers dislikes positive output gaps it has the advantage that the extent of asymmetry is parametrized by the coefficient γ. In particular, for $\gamma \to 0$, the linex tends towards the (symmetric) quadratic loss function. As we shall see later, this feature is attractive since, by nesting the quadratic as a particular case, the Linex leads to a formulation that lends itself to an econometric test of asymmetric.objectives As γ increases the extent of asymmetry progressively becomes stronger.[5]

2.2 Asymmetric inflation gap objectives

Each of the two functional forms discussed above can also be used to represent a precautionary demand for price stability. During periods of disinflation credibility building is a major concern inducing the CB to be more averse to positive than to negative inflation gaps. Such situations can be represented by rotating the loss functions in Figures 1 and 2 around the vertical axis so that losses, in each case, increase at a higher rate, for positive than for negative inflation gaps.

3 The precautionary demand for expansions and the new inflation bias

An interesting consequence of asymmetric objectives is that it may lead to an inflation bias even in the absence of a KPBG type of bias. In particular, the conjunction of a precautionary demand for expansions with uncertainty about upcoming economic shocks creates an inflation bias even when the output target of the CB is identical to potential output. The intuition underlying this new type of bias follows.

When current policies are chosen decision makers at the CB are uncertain about the real state of the economy at the time the planned policy is expected to impact it. Since the CB is more concerned about downward deviations of employment from its normal level than about upward deviations monetary policy is chosen so as to make the probability of erring on

[5]For $\gamma \to \infty$ the Linex is as near as it can be to the first specification. But it never quite reaches it, since the first specification has a break point at zero while the linex is continuous.

the side of tightness smaller than the probability of erring on the side of ease.[6] As a result planned monetary expansion and inflation are positive on average. Since they understand this tendency of the CB rational individuals expect a positive inflation. This pushes policymakers to be even more accomodating and creates, a somewhat higher, permanent inflationary bias. As in the standard model this bias is suboptimal. Although policymakers prefer to err on the side of expansion in order to reduces the probability of the costlier downward deviations of employment from its normal level the positive expecteded inflation neutralizes the effect of this policy on the distribution of employment. For concreteness this mechanism is illustrated in what follows in an economy characterized by a monetarist expectations augmented Phillips relation. But the same mechanism operates for other structures as well, as long as shocks are additive.[7]

3.1 An illustration of the new inflation bias[8]

The supply side of the economy is represented by an expectations augmented Phillips curve

$$Y = Y_n + \alpha(\pi - \pi^e), \tag{5}$$

where π^e is expected inflation, Y_n is the natural level of output and α is a positive parameter that characterizes the effect of unanticipated inflation on employment, and through it, on output. The natural level of output is subject to stochastic fluctuations and is given by

$$Y_n = Y_p + \epsilon \tag{6}$$

where $\epsilon = Y_n - Y_p$ is a temporary supply shock that affects the output gap.[9] For simplicity, ϵ is specified as a zero mean stochastic shock to the natural level of output with distribution

[6] This assumption is obviously realistic for the political establishement. In a world in which the CB is supposed to be, at least partly accountable, to elected officials this asymmetry is likely to permeate, perhaps to a lesser extent, the objectives of the CB. Although central banks today are substantially more independent from political authorities than ten years ago they are nonetheless expected by many to pay attention to the wishes of political authorities. Stiglitz (1998, p.19), for example, expresses the view that, since monetary policy is a key determinant of macroeconomic performance, removing it from the control of democratically elected officials should at least raise some questions.

[7] An analytical illustration of the same mechanism within a New Keynesian framework appears in section V of Cukierman (2002)

[8] **This illustration draws on Cukierman (2000).**

[9] Note that, in the absence of inflationary surprises ε is exactly equal to the output gap.

function $G(\epsilon)$. Inflation is determined both by the choice of monetary policy as well as by the realization of the shock, ϵ and is given by the following equation :

$$\pi = m - c\epsilon, \tag{7}$$

where m is the rate of inflation planned by the CB and c is a positive parameter that determines the effect of shocks to employment on inflation. Equation (7) states that, given planned inflation, actual inflation is lower the larger is the supply shock to the economy. Provided there is no instrument uncertainty, this formulation is consistent both with cases in which the policy instrument is the interest rate as well as situations in which it is some nominal stock. The loss function of the CB is asymmetric in the output gap and is given by equations (1), (2) and (3) above.

The sequence of events and the structure of information is as follows. First expectations, π^e, are formed and embedded into nominal contracts. In the second stage the CB picks the value of its instrument, m. Finally the stochastic real shock to employment, ϵ, realizes and determines, along with monetary policy, both employment and inflation. This sequence is illustrated in Figure 1. A crucial element is that, when it chooses the setting of its instrument, the CB is uncertain about the magnitude of the real shock to employment. This is *a fortiori* true for the public when they form their expectation. This timing of events reflects the realistic presumption that, when it picks mometary policy, the CB does not possess full information about the shocks that will affect the economy at the time its policy choice will impact the economy.[10]

Figure 1 : The Sequence of Events

1.π^e is formed——>**2.**policy, m, chosen——->**3.** ϵ realizes.

The shock, ϵ, affects employment directly, as well as indirectly by creating, given monetary policy, unanticipated inflation in a direction that is opposite to the sign of the shock. From equations (5) through (7) the combined marginal impact of the shock on employment is

[10]This point of view is consistent with Friedman's notion of "long and variables lags" between the choice of policy and its impact on the economy.

$$q \equiv 1 - \alpha c. \tag{8}$$

I assume that the direct effect of the shock on employment dominates its indirect effect via unexpected inflation so that q is positive. Minimization of the expected value of CB losses subject to equations (5) through (7) yields (after some manipulations) the following CB reaction function.[11]

$$m = \frac{1}{1+\alpha^2 AG\left[b(\pi^e - m)\right]}\left[\alpha^2 AG\left[b(\pi^e - m)\right]\pi^e - \alpha A q \int_{-\infty}^{b(\pi^e - m)} \epsilon dG(\epsilon)\right] \tag{9}$$

where $dG[.]$ is the density of ϵ and $b \equiv \frac{\alpha}{q}$.

I turn next to expectation formation which occurs at the first stage of the game. Although individuals do not know the realization of ϵ at this stage, they do know its stochastic structure as well as the structure of the economy and of CB objectives. Taking the expected value of inflation conditioned on this information as the operational proxy for the public's rational expectation of inflation and using equation (7), we obtain

$$E\pi \equiv \pi^e = m = -\alpha A q \int_{-\infty}^{b(\pi^e - m)} \epsilon dG(\epsilon) \tag{10}$$

where E is the expected value operator. In equilibrium both equations (9) and (10) must be satisfied. It follows that $\pi^e - m = 0$ so that equation (10) becomes

$$E\pi \equiv \pi^e = m = -\alpha A q \int_{-\infty}^{0} \epsilon dG(\epsilon) = -\alpha A q G(0) E\left[\epsilon \mid \epsilon < 0\right]. \tag{11}$$

$G[0]$ is the probability of a recession. More precisely it is the probability that the realization of the employment shock, ϵ, is lower than the mean of this shock which is zero. $E[\epsilon \mid \epsilon < 0]$ is the expected value of ϵ conditioned on the economy being in a recession (ϵ negative). Since the probability of a recession is positive and the expected value of ϵ conditioned on the economy

[11] The details of the derivation appear in Cukierman (2000).

being in a recession is negative both planned and expected inflation are positive. Furthermore, in spite of its attempt to reduce the size of recessions the CB has no influence on output which remains at its natural level. Had the CB precommitted to a zero rate of monetary expansion output would still be at its natural level. Hence there is an "inflationary bias" on average.

Intuitively, this bias arises because the CB is more sensitive to policy errors in which monetary policy is too tight than to policy errors in which it is too expansionary in conjunction with the fact that it does not have perfect information about the state of the economy. Hence an inflationary bias arises **even** when policymakers' aim at attaining potential output. The bias arises because policymakers are more averse to negative than to positive output gaps and because they are uncertain about the state of the economy.

As in the standard explanation for the existence of an inflation bias, the bias is an increasing function of the slope of the short run Phillips curve (α) as well of the relative importance attributed by policymakers to employment (A).[12] Hence, as in Rogoff (1985), the more conservative is the CB (the lower A), the lower is the bias. A novel element here is that, given those parameters, the bias is higher the higher is the probability of a recession, and the deeper this recession is expected to be, once it occurs. Thus if $G(.)$ is skewed to the right so that the mean median spread of ϵ is positive, the inflationary bias is larger than in the case in which it is symmetric around its mean. By the same token, the larger is the average size of the expected recession ($E[\epsilon \mid \epsilon < 0]$ is larger in absolute value) the larger is the bias. That is, other things the same, more real recession prone economies suffer from a higher inflationary bias. The broad intuition underlying this result follows. Due to their asymmetric attitude to recessions and to expansions, policymakers tend to create larger monetary expansion more when the likelihood, and the expected magnitude of a recession is higher. Since the public is aware of that it adjusts its inflationary expectation accordingly and neutralizes in the process any effects of monetary policy on employment and output. Thus, employment remains at its natural level but the bias is higher due to the stronger incentive of policymakers to inflate. Note, however, that this conclusion depends on the assumption that there is no precautionary demand for price stability.[13]

[12] Details on the standard bias appear in chapter 3 of Cukierman (1992).

[13] Nobay and Peel (1998) show that when **only** a precautionary demand for price stability is present there is a deflationary rather than an inflationary bias.

More on this later.

4 Empirical evidence and tests with monetarist transmission mechanisms

4.1 A testable implication using the first specification of asymmetric objectives

Cukierman and Gerlach (2003) provide a test of the new inflation bias mechanism by focusing on an implication that the new mechanism does not share with the KPBG bias mechanism. This test uses the fact that the conditional expected value of ϵ in equation (11) generally rises with the variability of ϵ. In particular, provided the distribution of the supply shock, ϵ, is normal, there should be a positive relation between average inflation in a country and the variance of shocks to output. Equation (11) implies that the average rate of inflation depends on the average expected magnitude of recessions which is given by the absolute value of the (negative) term, $E\left[\epsilon \mid \epsilon < 0\right]$. Assuming that the distribution of ϵ is normal with mean 0 and variance σ^2 equation (11) implies that the average rate of inflation is proportional to the mean of a normally distributed variable truncated from above at zero. Theorem 22.2 in Greene (1997, p. 951), implies that

$$E\left[\epsilon \mid \epsilon < 0\right] = -\sigma\phi(0)/\Phi(0) = -2\phi(0)\sigma. \tag{12}$$

where $\phi(\epsilon)$ and $\Phi(\varepsilon)$ are respectively the probability density and the distribution function of a standard normal variate. Equation (12) states that the mean of a normally distributed random variable truncated from above at zero depends inversely on the standard deviation of the variable. Intuitively, the greater the standard deviation, the more likely it is that the variable will assume a large negative value, and consequently the more negative is the expected value of the truncated distribution.[14]

[14] Although the formal argument is limited to normal distribution, this intuition suggests that the positive association between the expected depth of recessions and the variability of the supply shock extends to all symmetric distributions with a zero mean. Furthermore, symmetry is a sufficient but not necesssary condition for this association.

Inserting equation (12) into equation (11) we obtain

$$E\pi \equiv 2\alpha A q \phi(0)\sigma. \quad (13)$$

The key implication of equation (13) is that the average rate of inflation depends positively on the standard deviation of the shock, ϵ. Intuitively, the larger is σ, the more likely it is that large contractionary shocks will occur. As a consequence the interaction between the precautionary demand of policymakers for expansions and uncertainty about supply shocks induces a stronger inflationary reaction when the variability of shocks is higher. Since the public is familiar with this tendency of policymakers, inflation expectations are therefore also positively related to σ.

The new inflation bias mechanism implies that the slope parameter in a regression of average inflation on the standard deviation of the supply shock should be positive. By contrast, the traditional KPBG inflation bias story does not imply that such a relation should exist. It is therefore possible to perform a first pass test of the new mechanism by examining whether there is such a relation in the data. It also follows from equation (11) that this implication should hold only if the CB is not too conservative (A is not too small). As a matter of fact the theory predicts that, when central banks are highly independent and concerned mainly with inflation so that A is small, the positive relation between inflation and the variance of shocks to output should weaken and may even disappear.

4.2 A cross sectional test

Using the variance of real GDP growth as a proxy for the variability of the shock, ϵ, Cukierman and Gerlach test those implications by regressing average inflation in a cross section of 22 OECD countries on this variance between 1971 and 2000.[15] Since there have been, during this thirty years period, substantial changes in the effective level of CB conservativeness (as characterized by the parameter A) the same regressions have been repeated for two subperiods; 1971-1985

[15] The rationale for using this proxy is that, in the absence of anticyclical policy, the variability in the rate of growth of real GDP and the variance of shocks to GDP are positively and strongly related. Although stabilization policy may weaken this relation it is unlikely that it destroys it for at least two reasons. First, due to imperfect knowledge about the economy, stabilization policy is only partially successful. Second, since policymakers are also concerned about inflation, the stabilization of shocks to output is partial even in the absence of uncertainty.

and 1986-2000. It is well known that, worldwide, the level of effective CB conservativeness has been higher (implying a lower A) in the second than in the first subperiod.[16]

The main findings are that for the entire period, as well as for the first subperiod, there is a significant positive relation between inflation and the variance of real GDP growth. In the second subperiod this relationship is still positive but insignificant. Those findings are illustrated in Figures 3-5. Although these regressions are simple, the findings are sufficiently strong and clear cut to warrant the conclusion that, at least until 1985, the view that the central banks of (most if not all) developed economies possessed an inflation bias induced by a precautionary demand for expansions cannot be easily dismissed. Due to the substantial increase in CB independence during the 1990s such a sweeping conclusion is less appropriate today. But this still leaves the door open for the possibility that individual central banks may possess precautionary demands for expansions.

4.3 A single country test using the second specification of asymmetric objectives

Using the formulation of asymmetry in equation (4) Ruge-Murcia (2003) provides a specification that nests both the KPBG inflation bias as well as the new inflation bias mechanism into one framework and compares their abilities to explain the behavior of US inflation. In this specification the phase of the cycle is proxied by the rate of unemployment rather than by the output gap. More precisely, the CB loss function is given by

$$\frac{A}{\gamma^2}\left\{\exp(\gamma(u_t - u_t^*)) - \gamma(u_t - u_t^*) - 1\right\} + \frac{1}{2}(\pi_t - \pi_t^*) \tag{14}$$

where u_t is the rate of unemployment in period t, u_t^* and π_t^* are the targets rates of unemployment and of inflation and, as before, A represents the relative importance attributed by the CB to stabilization of employment versus stabilization of inflation. The natural rate of unemployment,

[16] See for example Cukierman (1998) for an early assessment of this process.

u_t^n, is stochastic and, therefore not perfectly known by the CB. Let

$$E_{t-1}u_t^n \tag{15}$$

be the expected value, as of period $t-1$, of the natural rate of unemployment in period t. The target rate of unemployment may or may not be equal to this expected value. More precisely

$$u_t^* = kE_{t-1}u_t^n. \tag{16}$$

When $k = 1$ the CB targets the expected value of the natural rate of unemployment and there is no KPBG bias. When $k < 1$, the target rate of unemployment is smaller than the expected value of the natural rate and **there is** a KPBG inflation bias. The expectations augmented Phillips curve in terms of unemployment is given by

$$u_t - u_t^n = -\lambda(\pi - \pi^e) + \eta_t \tag{17}$$

where λ is a positive parameter and η_t is a stochastic shock. The CB has imperfect control over the rate of inflation. In particular

$$\pi_t = i_t + \varepsilon_t \tag{18}$$

where i_t is the policy instrument and ε_t is the control error. At time $t-1$, before the realizations of the stochastic variables in period t are revealed the CB chooses the policy instrument so as to maximize the expected value of objectives in equation (14) subject to the economic structure given in equations (17) and (18). This yields an implicit expression for the instrument i_t. Substitution of this expression into equation (18) yields, after some algebra[17]

$$\pi_t = \pi_t^* + \frac{\lambda A}{\gamma}\left\{\exp\left(\gamma(1-k)E_{t-1}u_t^n + \frac{\gamma^2}{2}\sigma_{u,t}^2\right) - 1\right\} + \delta_t \tag{19}$$

where $\sigma_{u,t}^2$ is the variance of unemployment conditional on information available in period t and δ_t is a combination of innovations to the various stochastic shocks of the model. This

[17]Further details appear in Ruge-Murcia (2003).

expression nests the KPBG bias and the Cukierman (2000) bias as two special cases. When $\gamma \to 0$ (symmetric objectives) and $0 < k < 0$ equation (19) reduces to

$$\pi_t = \pi_t^* + \lambda A(1-k)E_{t-1}u_t^n + \delta_t \tag{20}$$

implying that inflation is higher the higher is the expected natural rate of unemployment, as in the KPBG framework. When $k = 1$, there is no KPBG bias and equation (19) reduces to

$$\pi_t = \pi_t^* + \frac{\lambda A}{\gamma}\left\{\exp\left(\frac{\gamma^2}{2}\sigma_{u,t}^2\right) - 1\right\} + \delta_t. \tag{21}$$

Since γ and $\sigma_{u,t}^2$ are both positive the expression in curly brackets is positive producing the new, Cukierman (2000) type, bias. As in subsection 3.1 this bias is due to the conjunction of asymmetric employment objectives and uncertainty. Note that, analogously to the first specification of the loss function, this bias is an increasing function of the conditional variance of unemployment. Thus, the existence of a KPBG bias implies that inflation should be an increasing function of the expected natural rate of unemployment and the existence of a Cukierman (2000) bias implies that inflation should be an increasing function of the conditional variance of unemployment. It is therefore possible to evaluate the relative importance of those two hypotheses by regressing inflation on the expected natural rate of unemployment and on the conditional variance of unemployment. Linearization of equation (19) yields the precise form of the regression to be estimated which is

$$\pi_t = a + bE_{t-1}u_t^n + c\sigma_{u,t}^2. \tag{22}$$

If both types of biases operate, both b and c should be positive and significantly different than zero. If only one of them is operative, only its coefficient should be significantly different than zero. Estimation of equation (22) requires proxies for $E_{t-1}u_t^n$ and for $\sigma_{u,t}^2$. This is done by postulating particular stochastic structures for the natural rate of unemployment and for its association with actual unemployment and by using a Garch model to characterize over time changes in the variability of unemployment.

Using this methodology, Ruge-Murcia (2003) estimates equation (22) on quarterly US data between 1960 and 1999, and finds that b is not significantly different than from zero but that c is positive and significant. Furthermore, various statistical tests reject the hypothesis that the KPBG hypothesis can explain US inflation during this period. However the same tests cannot reject the hypothesis that US inflation is explained by the conjunction of uncertainty and asymmetric CB objectives.

5 Coexistence of precautionary demands for expansions and for price stability with a New Keynesian transmission mechanism

The precautionary demand for expansion may exist in some countries and not in others. Furthermore, it may be in evidence, within a given country, in some subperiods and not in others. Similar observations apply, perhaps even more, to the precautionary demand for price stability. During periods of inflation stabilization a precautionary demand for price stability may emerge and dissapear, later on, after a sufficiently long period of price stability has been experienced.

Utilizing a New Keynesian transmission mechanism Cukierman and Muscatelli (2003) propose a framework that features both types of precautionary demands and a general specification of asymmetries. In such frameworks the instrument of monetary policy is taken to be the short term nominal interest rate of the CB. Since, within New Keynesian frameworks, prices are temporarily sticky the choice of this rate affects the real rate of interest, and through it, the output gap and inflation. Maximization of CB objectives subject to the structure of the (New or Neo Keynesian type) economy yields the so called "Taylor rule" that relates the short term nominal rate to the output gap and to the inflation gap.

It is well known that, in the absence of precautionary demands for either expansions or for price stability (quadratic objectives) the Taylor rule is linear. Cukierman and Muscatelli (2003) show that in the presence of both types of precautionary demands (asymmetric objectives with respect to both inflation and the output gap) the Taylor rule is likely to be non linear but that it is not **necessarily** non linear. The reason is that the presence of **only** a precautionary demand for expansion induces a concave Taylor rule while the presence of **only** a precautionary demand for price stability induces a convex Taylor rule.

In the presence of both types of precautionary demands those two tendencies may offset each other to an extent that preserves linearity of the Taylor rule by chance. Obviously, one of those tendencies may dominate the other even if both types of precautionary demands exist. Cukierman and Muscatelli (2003) show that, if the precautionary demand for price stability dominates, the Taylor rule will be convex whereas, if the precautionary demand for expansions dominates, the Taylor rule will be concave. Using quarterly data on the USA, Germany, Japan and the UK between 1979 and 2000, they estimate linear Taylor rules of the type suggested by Clarida, Gali and Gertler (2000) and test for the possible existence of non linearities. They find **some** evidence in favor of non linearities in all four countries. This evidence is strong for the US and the UK, the less so for Japan and is weakest for Germany. Building on those results they proceed to estimate non linear Taylor rules of the form

$$i_t = (1-\rho)\{\widehat{\alpha} + \beta_1 \pi_{t,1} + \gamma_1 x_{t,1} + \beta_2 \pi_{t,1} F_\pi(\pi_{t,1}) + \gamma_2 x_{t,1} F_x(x_{t,1})\} + \rho i_{t-1} + \varepsilon_t \tag{23}$$

by GMM. Here i_t is the nominal rate of interest, $\pi_{t,1}$ and $x_{t,1}$ are inflation and the output gap in period $t+1$, and $F_\pi(\pi_{t,1})$ and $F_x(x_{t,1})$ are non linear functions that characterize the potential non linearity of the rule.[18] When $\beta_2 = \gamma_2 = 0$ the Taylor rule is linear. The theory implies that there should be a particular systematic relation between the coefficients β_2 and γ_2 of the non linear segments. This restriction is imposed on the estimation procedure implying that β_2 and γ_2 have the same sign. When β_2 and γ_2 are positive so that the Taylor rule is convex there is evidence in favor of a dominant precautionary demand for price stability. On the other hand, if they both are negative, so that the Taylor rule is concave there is evidence in favor of a dominant precautionary demand for expansions.

The estimation results suggest that there is substantial variety in the relative importance of the two precautionary demands both across countries and, in some cases, within a given country over time. Thus, for the entire sample period, the Taylor rules for the US Germany and Japan are convex pointing to the dominance of a precautionary demand for price stability, while the Taylor rule for the UK is concave supporting the existence of a dominant precautionary demand for expansions. Figure 5 illustrates the convexity of the US Taylor rule over the full

[18] Those functions are specified as hyperbolic tangents.

sample. Interestingly, when the period of Volcker's disinflation is excluded from the sample a dominant precautionary demand for expansions emerges in the US. Figure 6 illustrates the concavity of the US Taylor rule after the conquest of inflation in this country. By contrast when the early period is excluded for the UK a dominant precautionary demand for price stability emerges in this country. The last finding is consistent with the fact that the UK stabilized inflation only during the nineties.

Those findings are consistent with the view that, except for strongly inflation averse countries like Germany and Japan in which a precautionary demand for price stability is present over the entire sample period, such a precautionary demand is likely to become dominant mainly during periods of inflation stabilization.

6 Concluding Remarks

The literature of the last five years on asymmetric CB objectives and non linear reaction functions provides a new perspective on the policy roots of inflation in developed economies. Rather than being due to a systematic attempt to maintain employment above its natural level (or output above potential) this literature raises the possibility that much of the inflationary bursts experienced by those countries during the last thirty years were due to the existence of a precautionary demand for expansions. It thereby provides an alternatve to the KPBG explanation for excessively loose monetary policies.

But this literature also suggests that, during periods in which the CB and/or the political establishement resolve to stabilize inflation is strong, the precautionary demand for price stability may dominate. In addition to the econometric evidence discussed in the previous section, recent undershootings of the inflation target by the Bank of Israel and the Bank of England provide anecdotal evidence in favor of this hypothesis.

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Figure 1

Asymmetric Output Gap Objectives and the Precautionary Demand for Expansions

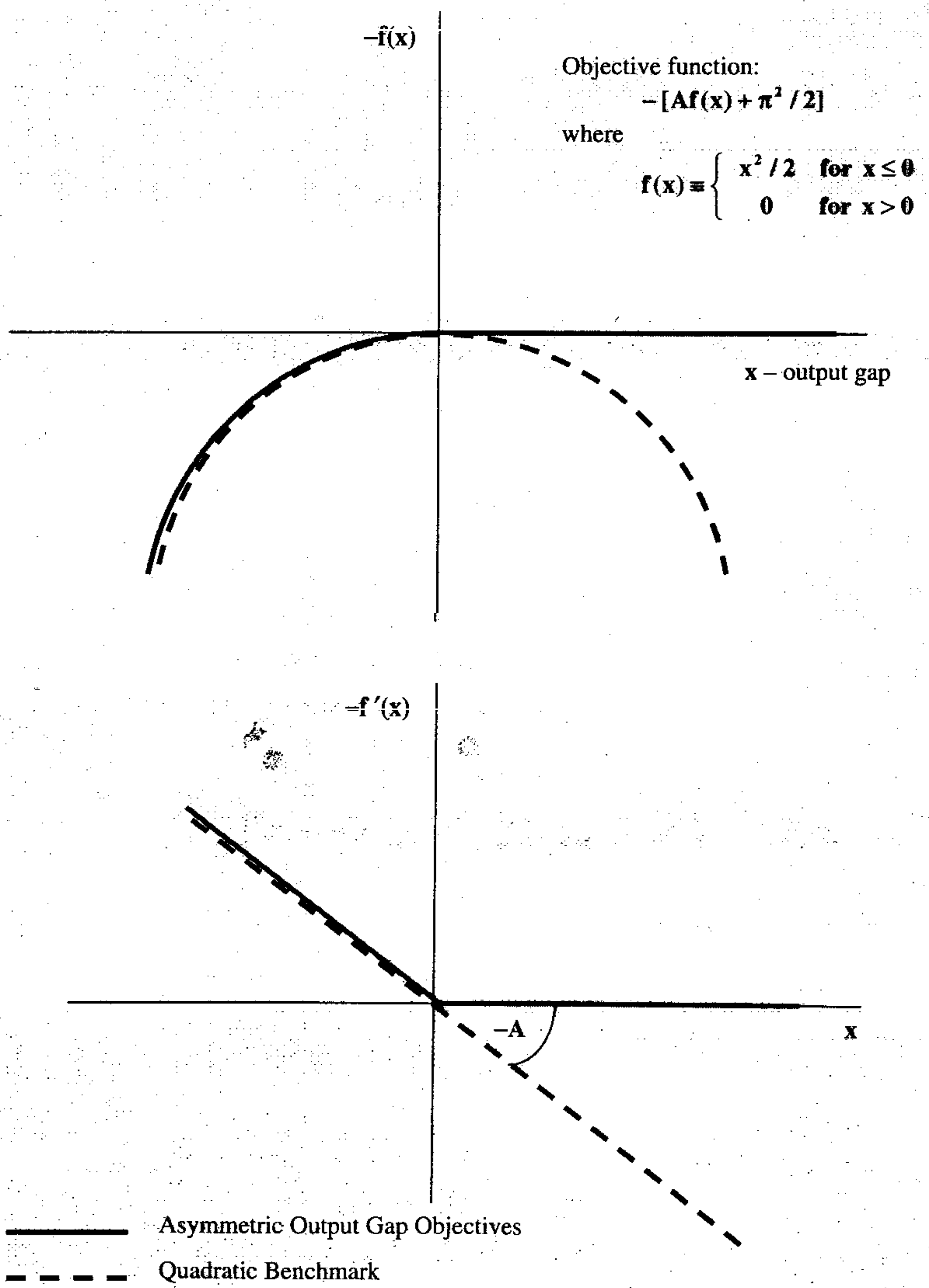
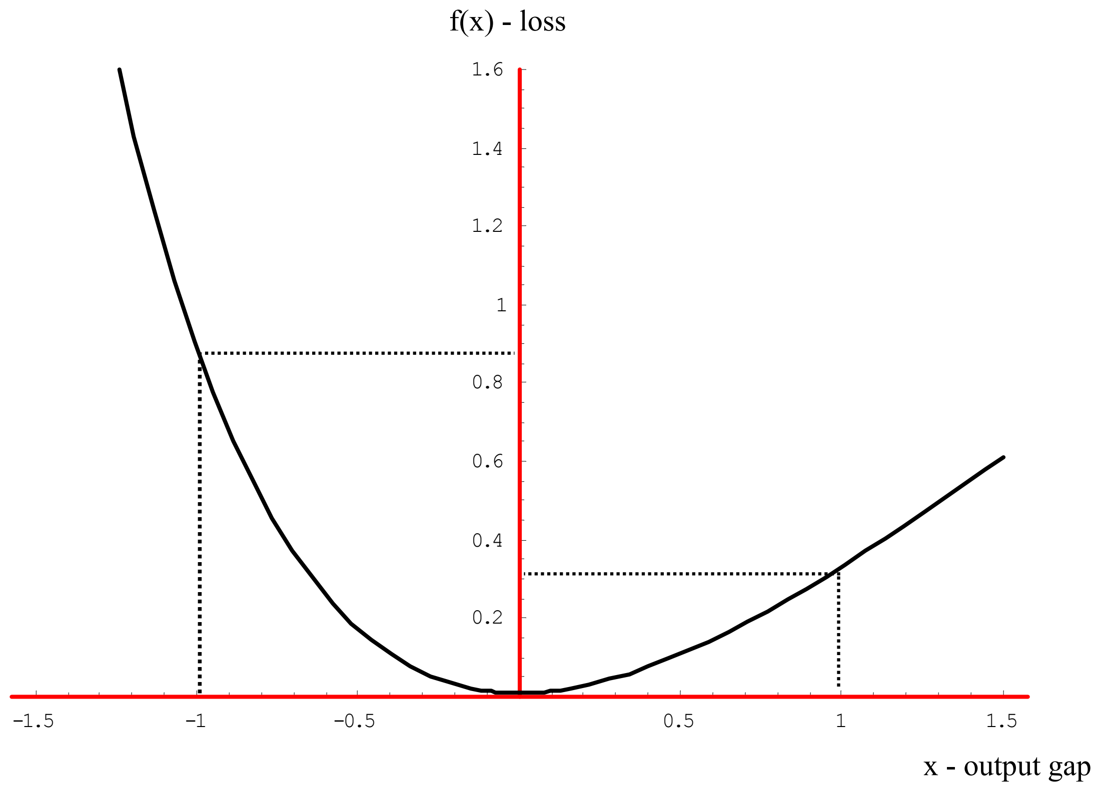


Figure 2: Asymmetric Output Gap Objectives and the Precautionary Demand

For Expansions (Second Parameterization - Linex)



Note: $f(x) \equiv \text{Exp}[(-\gamma\ x) + \gamma\ x - 1] / (\gamma^2)$. The figure is for $\gamma = 1.5$.

Figure 3:

Average Inflation and Standard Deviation of Real GDP Growth, 1971-2000

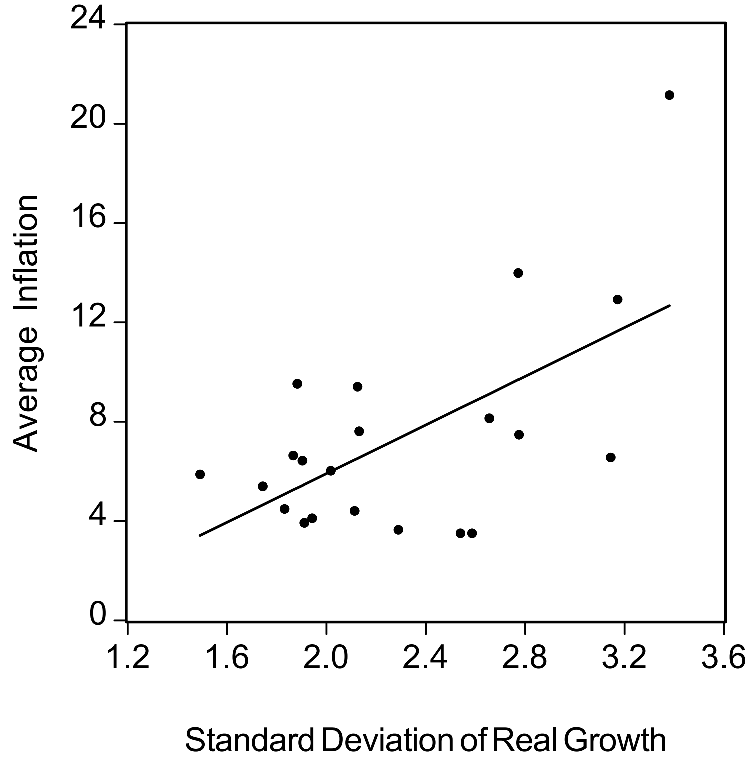


Figure 4a:

Average Inflation and Standard Deviation of Real GDP Growth, 1971-1985

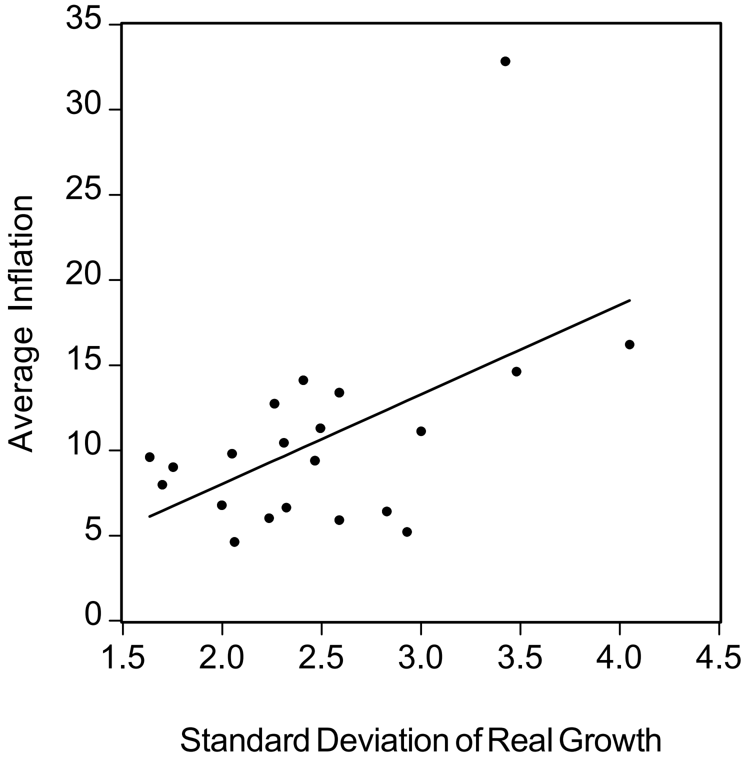
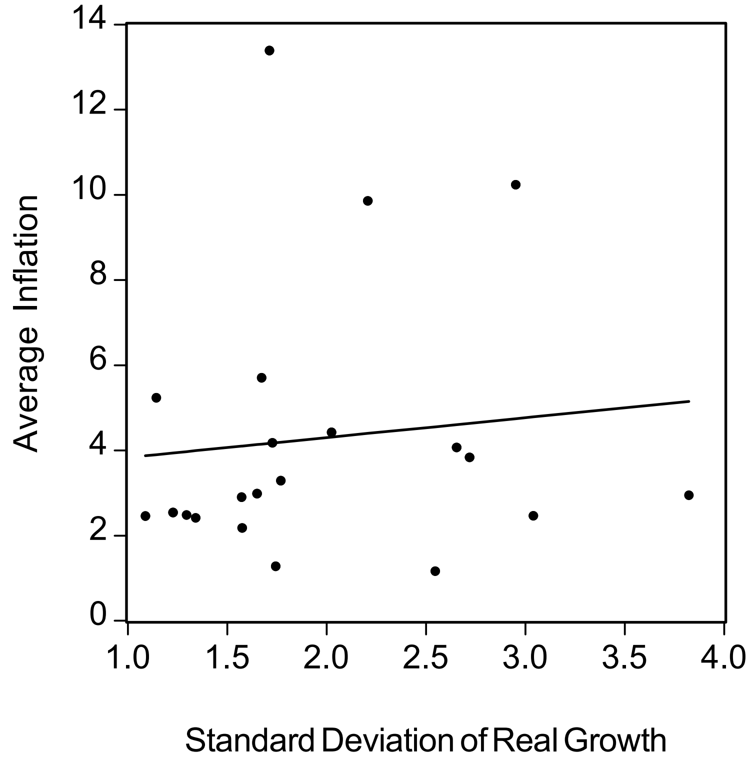


Figure 4b:

Average Inflation and Standard Deviation of Real GDP Growth, 1986-2000



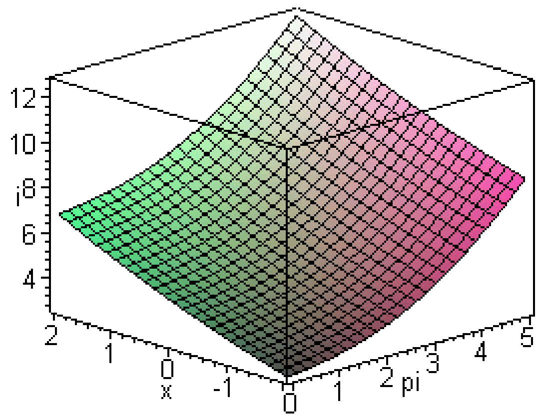


Figure 5: Non-Linear Reaction Function, USA 1979-2000

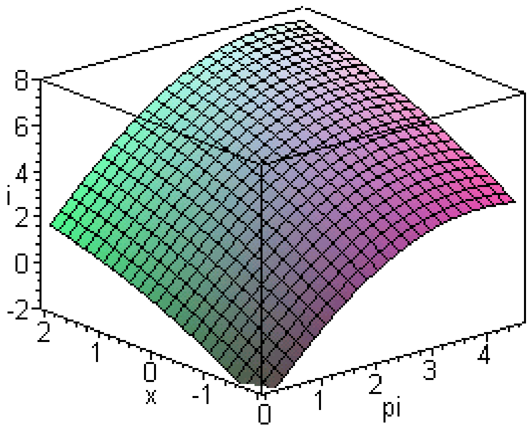


Figure 6: Non-Linear Reaction Function USA 1985-2000