Nonlinear economic policies: Pitfalls in the Lucas critique empirical counterpart

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Abstract

This paper provides a showcase for the possibility of non–linear monetary rules. We show that, at least for the US, France and Germany, Taylor type rules can be generalized to non–linear forms involving a STAR representation that leads to a deterministically varying coefficients rule. Inflation targeting then appears to be negatively correlated to lagged output gap whereas output gap targeting is positively correlated.

An attractive feature of this modelling is that it furnishes an explanation for the empirical "quantitative irrelevance" of the Lucas critique. Indeed, most of the tests for the Lucas critique are conducted in a linear or linearized framework, which cannot account for non–linearities. Structural changes detected in the monetary policy rules may only be the sign of misspecification problems, in which case no behavioral changes should be expected.

Keywords: *Monetary policy, Taylor rules, non–linearities, varying coefficients, Lucas critique.*
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Introduction

A growing bulk of empirical studies has found evidence for structural breaks in the design of monetary policy. According to Lucas' [1976] seminal article, such breaks are expected to alter the reduced form estimates of behavioral equations. More precisely, Lucas argued that private agents rationality and their forward–looking behavior imply that parameters of reduced forms based econometric models do not remain constant in face of structural breaks in the form of economic policy. Otherwise stated, quantitative evaluations of alternative economic policies based on reduced form do not provide any reliable statistical information to practitioners and can even lead to spurious economic policy recommendations.

If the Lucas critique constitutes an important theoretical benchmark, empirical evaluations of its quantitative relevance have yielded mitigated results and empirical evidence provides little support for the Lucas critique. Most of these tests have been evaluated in the context of super–exogeneity tests advocated by Engle, Hendry and Richard [1983]. More recently, another route has been pursued by Estrella and Fuhrer [1999]. They provide some empirical evidence for greater stability of estimations based on backward looking model rather than on forward looking model, which sounds like a paradox since if the Lucas critique were valid, forward–looking models should yield more stable estimates. Ericsson and Irons [1995] further review a large bunch of empirical studies leading to cast doubt on the empirical relevance of Lucas' argument. Otherwise stated, traditional econometric approaches for economic policies evaluations are robust.

However, recent works (see e.g. Lindé [1999] among others) underline the lack of power of super exogeneity tests, while others (see e.g. Ireland [1999] or Collard, Fève and Langot [1999]) argue that the use of *ad hoc* models that do not take advantage of a more specified general equilibrium model may give rise to low powered statistical tests of the Lucas critique. From a more theoretical point of view, Farmer [1996,1999] shows that taking learning mechanisms or the possibility for indeterminacy into account may lead to unrecoverable Lucas critique, as private decision rules can then be expressed as a backward–looking process that does not explicitly depend on

economic policy parameters.

In this paper, we pursue another route, remarking that most of the literature has been confined to a linear world whereas there are many reasons to think that policy rules may be nonlinear by nature. For instance, monetary authorities may be expected to respond differently to deviations of aggregates from their targets depending on the magnitude and the sign of these deviations as well as the state of the business cycle. If so, conventional econometric analysis may not provide anymore relevant tools to tackle the Lucas critique for at least two reasons:

- First, what is usually identified with a structural break may not result from a change in the policy rule itself but rather from a modification in the business cycle features. Then, agents behavior should not be affected.

- Second, nonlinearities in policy rules may translate into an observational equivalence property. Indeed, in a nonlinear framework, changes in the structural parameters of the policy rule do not necessarily involve a significant change in the outcome of the policy rules.

In such a framework standard exogeneity testing procedure may suffer from a lack of power and may not be able to detect the implications of the Lucas critique.

This paper aims precisely at illustrating such a shortcoming and provides evidence in favor of nonlinearities in monetary policy rules. We estimate a reaction function for both the FED and French and German central banks in the lines of Taylor [1993] and Clarida, Gali and Gertler [1998] and extend it to a nonlinear setup allowing for two different extreme regimes. The transition from the high (expansion) to the low regime (recession) is modeled by a smooth transition function, such that the model lies in the class of STAR models. Our results clearly support a nonlinear representation of the monetary authorities behavior for our sample. We then argue that the non–linear framework we set up provides some rationale to the failure of standard test of the Lucas critique.

The plan of the paper is as follows. A first section presents the basic theoretical model, insisting on the form of non–linearity we will deal with.

A second section is devoted to the data and the estimation strategy. Section 3 proposes our results and discusses their implications in terms of the Lucas critique. A last section offers some concluding remarks.

1 Toward a nonlinear monetary policy rule

Recently, Taylor [1993] has proposed to capture the essential ingredients of the FED policy using a simple reaction function. Starting from the simple observation that the FED's main operating intrument of monetary policy is a short–term interest rate — an interbank lending rate for overnight loans — Taylor proposes a policy rule that describes how the FED sets the level of the nominal interest rate along the business cycle. He proposes to link the nominal interest rate to inflation and output gaps according to the following rule

$$i_t = 2 + \pi_t + 0.5(\pi_t - 2) + 0.5x_t \tag{1}$$

where i_t denotes the nominal interest rate, π_t is the inflation rate and x_t is a measure of the output gap. Then, according to (1) any positive deviation of the inflation rate from its targeted value (2%) leads the FED to increase the level of the interest rates. This component therefore aims at stabilizing the nominal side. Likewise, any increase in the output gap results in an increase of the nominal interest rate. This latter component actually acts as an automatic stabilizer on the real side. Although very simple, this rule is intended to capture the essential elements of more realistic monetary policies for which the FED cares for "everything". Thus, this simple and fairly general rule is taken to be a good device for capturing and representing the way monetary policy is conducted by the FED. Implicit in that formulation is the fact that domestic monetary policy is not subject to any significant external constraint, such as fixed exchange rate parity, which turns out to be the case at least in the US.

However, although they admit to react according to basic Taylor's rule principles, central bankers claim to adopt a more subtle and more sophisticated behavior and claim that they take into account their forecasts on inflation and/or output gaps. Thus, in order to take all these features into account, Clarida et al. [1998] propose to extend the previous rule to the

following specification

$$i_t = \rho(L) i_{t-1} + (1 - \rho(1)) i_t^\star + \varepsilon_t \tag{2}$$

where $\rho(L)$ is a lag polynomial, with all roots lying outside the unit circle. $i_t^\star$ is the target rule that actually represents the "true" interest rule

$$i_t^\star = \alpha + \gamma(E_t \pi_{t+k} - \pi^\star) + \beta E_t x_{t+j} \text{ with } k > 0, j \in \mathbb{Z} \tag{3}$$

x_t is the output gap[1], π_t is the annual inflation rate and $\pi^\star$ is the inflation rate target. This specification departs from Taylor's in at least two ways. First of all, it explicitly takes into account expectations of central bankers in conducting the monetary policy. Therefore, any expected increase in the inflation rate or the output gap leads the monetary authorities to increase the nominal interest rate. Second, this specification (equation (2)) includes lags. At a first glance, one may refer to interest rate smoothing since empirical evidence on the nominal interest rate autocorrelation provides some support for such a phenomenon. Clarida, Gali and Gertler's study suggests another rationale for introducing these lags. Indeed, they face a measurement problem because they use the federal fund rate as the policy instrument. However, there are two measures of the federal fund rate in the US. The first one — the one they use — is the interest rate that clears the money market and therefore takes into account market phenomena. The second one is the interest rate that the FED actually sets and announces, which corresponds to $i_t^\star$ in (2). In others, the first measure corresponds to the policy rule instrument plus other phenomena that occur on the money market (speculation ...). These are precisely these phenomena that the lagged component actually attempts to capture. Therefore, Clarida, Gali and Gertler assume that market departures from the announced rule can be modelled as an AR process. In this study, we depart from this specification by using administrated data: there are no money market phenomena in our measure of the interest rate such that we will concentrate on the specification of $i_t^\star$.

[1] $x_t = \log(Y_t) - \log(Y_t^\star)$, where $Y_t^\star$ denotes potential output, modelled as a quadratic trend in Clarida et al. [1998].

More important in the rule are the reaction coefficients of the central bank to deviations in the inflation and output gap, γ and β. These coefficients have attracted a great deal of attention as any change in either γ and β can be interpreted as a change in the policy rule pursued by the central bank[2] and translates in changes in the behavior of private agents, that tests for the Lucas critique attempt to detect (see e.g. Estrella and Fuhrer [1999]). Clarida et al.'s [1998] specification assumes that γ and β are constant along the business cycle, such that changes to γ and β are basically associated to changes in the rule and ineluctably translate into changes in private agents decision rules. However, exogeneity tests usually fail to detect such modifications in the decision rules and the empirical relevance of the Lucas critique is often underestimated. We depart from this approach and allow for fluctuations in the reaction parameters along the business cycle. We thus consider a nonlinear behavior of the monetary authorities and consider the following modelling

$$\begin{aligned} i_t^\star &= \alpha + f(x_{t-d};\theta,s)\left[\gamma_0(E_t\pi_{t+k}-\pi^\star)+\beta_0 E_t x_{t+j}\right] \\ &\quad +\gamma_1(E_t\pi_{t+k}-\pi^\star)+\beta_1 E_t x_{t+j} \end{aligned} \tag{4}$$

where $d,k,j>0$. $f(x_{t-d};\theta,s):\mathbb{R}\longrightarrow(0,1)$ is a continuous mapping that we assume to take the following form

$$f(x_{t-d};\theta,s)=\{1+\exp(-\theta(x_{t-d}-s))\}^{-1}$$

This last assumption intends to account for non–linearities in the conduct of monetary policy, in that it leads to different monetary policies depending on the state of the business cycle (BC). Different variables may have been candidates to enter the transition function, among which the inflation rate (or the nominal exchange rate in Europe). We however restrict our attention to the output gap, as it is expected to capture the essential of the state of the business cycle. This assumption aims at capturing the fact that monetary authorities may adopt a more (less) aggressive reaction to deviations of inflation and output gap from their target depending on the state of the business cycle. Lagged output gap provides sufficient information on the

[2]This is also true for α and the coefficients of the lag polynomial.

state of the BC, at least for central bankers. The underlying idea behind such a modelling is that recessions may put some additional pressure on the central bank to be more aggressive in its stabilization policy. On the contrary, recessions — if accompanied by a higher inflation rate — may be a time for accommodation.

This assumption has one important implication on the FED response to inflation and output gap deviations as it puts varying weights on inflation and output gap stabilization. Actual weights are indeed given by:

$$\beta_t = \beta_1 + \beta_0 f(x_{t-d}; \theta, s) \tag{5}$$

$$\gamma_t = \gamma_1 + \gamma_0 f(x_{t-d}; \theta, s) \tag{6}$$

Hence the rule may be rewritten as:

$$i_t^\star = \alpha + \gamma_t(E_t\pi_{t+k} - \pi^\star) + \beta_t E_t x_{t+j} \tag{7}$$

It is worth noting that, contrary to standard varying coefficient methods, this assumption is compatible with the status of rule of equation (4) as the way coefficients vary is deterministically fixed, even if the coefficient is stochastic (through the threshold variable). Hence, these coefficients are also simple rules followed by central bankers: once the state of the business cycle *observed*, the coefficient is set.

One important implication of this modelling is that changes in the elasticities of the nominal interest rate to inflation and the output gap do not necessarily correspond to changes in the "deep" parameters of the policy rule. Then, if the non–linear model is supported by the data, changes in the reaction of the central bank do not necessarily correspond to modification in private agents policy rules. A strong implication of this analysis is that the detection of structural breaks in linear policy rule that are not associated to changes in private economic behaviors do not necessarily reveal the quantitative irrelevance of the Lucas critique but rather a misspecification of the policy rule.

2 Estimating strategy and data

The estimation is conducted on monthly data for the US, the French and the German economy. The sample runs from the early eighties to late nineties

for each economy. The inflation rate is the annualized CPI based inflation rate.[3] Finally the output gap is measured by the Hodrick–Prescott cyclical component of the industrial production index. The nominal interest rate is measured by

- The announced federal fund rate in the US;
- The Lombard rate in Germany, measured in the middle of the month;
- The intervention rate in France (monthly average).

The model is estimated using a Generalized Moment Method. The estimates of the variance–covariance matrix is robust to heteroskedasticity and MA(12) autocorrelation. A Parzen kernel was used.

We further had to put some preliminary assumptions on the form of the rule. First, following Clarida et al. [1998], we set both k and j to 12 in the US, such that the central bank reaction function is based on annual expectations. This choice was dictated by empirical evidence from cross–correlogram in France and Germany, reported in figure 1. This yields us to choose the inflation rate leaded of 3 and 6 months respectively in France and Germany and the output gap lagged of 12 months both in France[4] and Germany. d, the lag of the output gap in the transition function, is set to 3. This choice builds on the evidence that most of the decisions are based on the state of the business cycle in the last (observed) quarter.

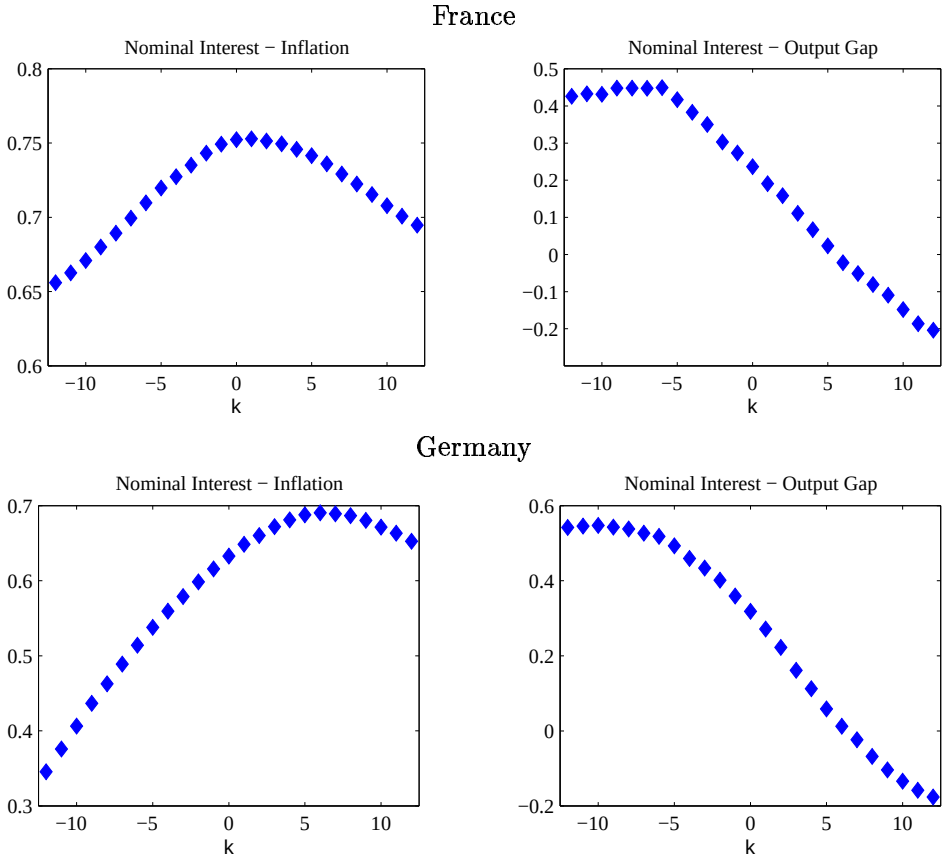
Further, for identifiability sakes, we needed to impose s, the threshold in the transition function. The selection of a value for this parameter relies on a procedure developed by Tsay [1989]. This procedure involves recursive estimation of ordered regressions[5], providing recursive residuals, coefficients and T-statistics. In this framework, as long as the value of the threshold is not included in the sample, the threshold model behaves like a linear model. When the threshold is reached, the nonlinear model corresponds to

[3] Annualized CPI based inflation rate is given by $\pi_t = 100 \times \log(CPI_t/CPI_{t-12})/12$.

[4] Inspection of the cross–correlogram actually indicates a lag of 6 months for France, but estimation problems led us to choose a lag of 12 months. This should not be of that much quantitative importance as the cross–correlogram appears to be very flat for lags ranging from 12 to 6.

[5] The data are ordered according to the values of the threshold variable, either increasing or decreasing ordering.

Figure 1: Cross–correlations



the combination of two (or more) regressions. Therefore, the profile of the recursive residuals and statistics changes when the value of the threshold is reached. It is thus possible to detect this value by inspecting the plots of the recursive coefficients and associated T-statistics against the threshold variable. Indeed, when a coefficient is significantly different from zero, its T-statistic converges regularly toward a given value while adding additional observations. Then, when the threshold value is reached, estimates do change and so do their T-statistics. The threshold detection thus consists in locating the first break in the plot, starting from the smallest observation of the threshold variable for an increasing ordering, and from the highest one for a decreasing ordering.

Again for identifiability sakes, we have to impose a value for $\pi^\star$. We set it to its empirical counterpart, *i.e.* the mean of π_t. This amounts to assume that the central bank was quite successful in conducting its monetary policy, as it satisfied, in average, its target.

3 Estimation results

This section reports our results for the three economies under study.

First of all, it appears from table 1 that the model cannot be rejected based on the standard overidentification test as the associated p–value is greater than 98% for each economy. Further, apart from the reaction coefficient to expected inflation in the linear part of the US rule, all coefficients are significant at the 5% confidence level. In others, based on these results, a non–linear specification cannot be rejected at the 5% confidence level.

We now attempt to characterize the form of non–linearity that arises from this experiment. First of all, it shall be stressed that the threshold s that makes the monetary policy shift from one regime to the other is quite close among countries. This is especially true for the US and Germany. But even more interesting is the fact that the form of the transition from one regime to the other is very similar among the economies under study, as can be seen from figure 3. However, the transition, although smooth, seems to be sharper in Europe than in the US, which might be explained by the fact that the nominal interest rate has evolved in a smoother way in the US than

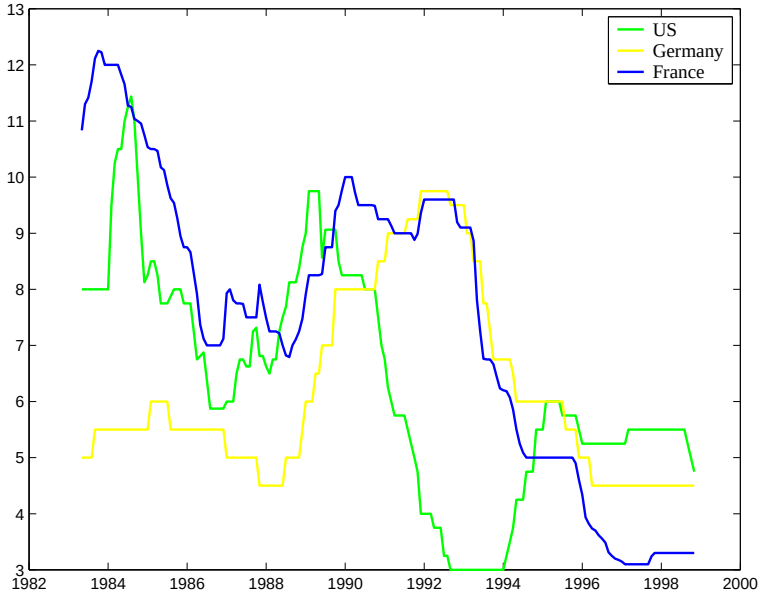
Table 1: Monetary policy functions

	USA	Germany	France
	1981:1–1998:8	1982:12–1997:11	1984:7–1997:11
θ	-1.05661	-1.05672	-7.70363
	(0.16838)	(0.19113)	(1.79737)
γ_0	5.22534	1.63647	0.98093
	(0.56120)	(0.23149)	(0.07484)
β_0	-0.70706	-0.73428	-1.00703
	(0.07187)	(0.08342)	(0.03381)
γ_1	-0.07818	-0.15864	0.77944
	(0.30924)	(0.11270)	(0.03817)
β_1	-0.40982	0.86585	0.74018
	(0.03158)	(0.05059)	(0.01771)
α	8.78973	6.52981	7.68359
	(0.05655)	(0.06253)	(0.03862)
J–stat	21.46	17.90	17.18
	[0.99;55]	[0.97;31]	[0.99;43]
SSR	1205.41	233.44	343.45
σ_ε	2.4248	1.34	2.23
s	0.76	0.88	-0.05
$\pi^\star$	3.81	2.48	3.15

Note : Standard deviations into parenthesis, p–value and degree of freedom into brackets. The set of instruments contains the inflation rate, the output gap, the nominal interest rate, the interest spread and money growth (M2) lagged up to 12 periods. Estimates are obtained by GMM with correction for MA(12) autocorrelation, optimal weighting matrix is obtained using a Parzen kernel.

in Europe, as figure 2 seems to indicate.

Figure 2: Nominal interest rates



This European sharpness is reflected in the evolution of the true elasticities of the nominal interest rate with respect to the inflation gap , γ_t and the output gap, β_t, which provides the only relevant information from that experiment. As aforementioned, the now statistically significant regime switching assumption implies that monetary authorities react in a different way depending on the state of the business cycle as figures 4 and 5 show.

As can be seen in figure 4, the reaction to inflation deviations has varied a lot within the period in all countries, but with significant differences among the three countries. First of all, it seems from table 2 that the US FED has had a greater average reactivity to inflation deviations than the French and German central banks, as $E(\gamma_t)$ is around 3 in the US, compared to almost 1 in Europe. From a theoretical point of view, this suggests the determinacy of real equilibrium in the US over the period. This is a big issue in the literature, which insists on that particular point: Taylor rules often lead to real indeterminacy or endogenous business cycles (See e.g. Benhabib, Schmitt-Grohé and Uribe [1998] for a global dynamic analysis). For instance, Clarida et al. [1998] show that the Taylor rule estimated for

Figure 3: Transition functions

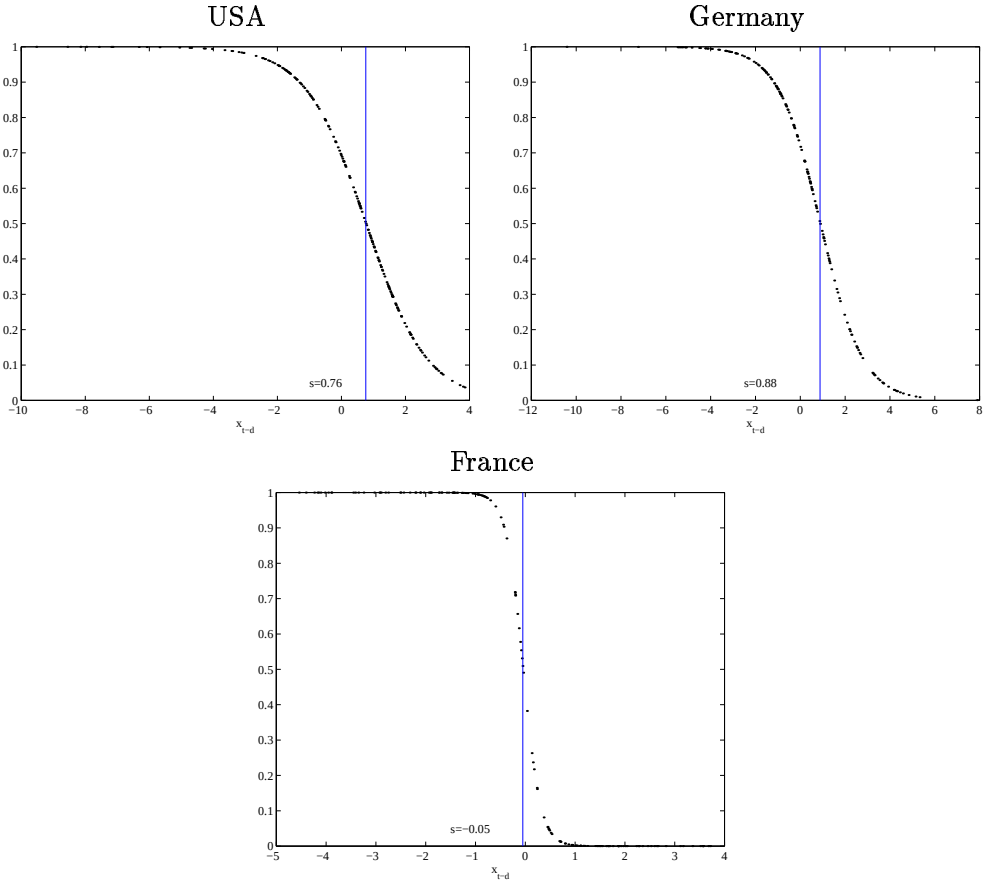
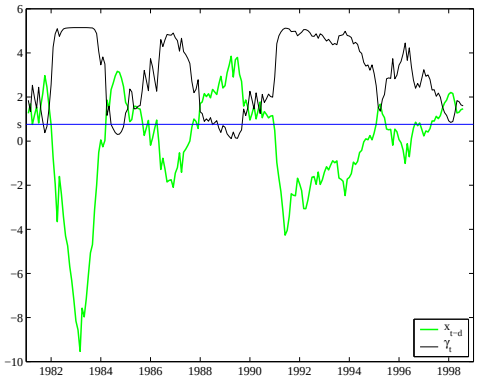
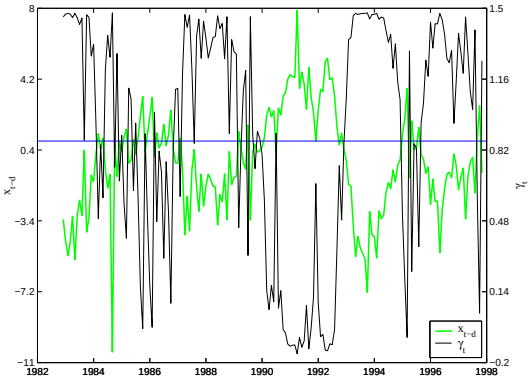


Figure 4: Inflation targeting (γ_t)

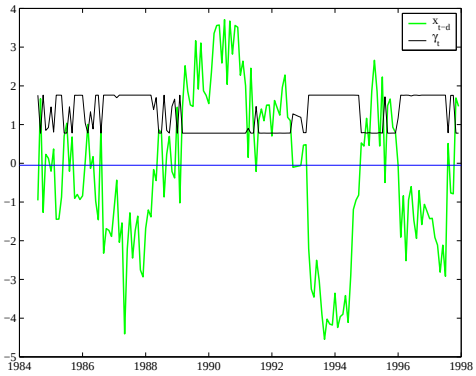
USA



Germany



France



the pre–Volcker period would have led to real indeterminacy. Similar results are found by Christiano and Gust [1999] within a liquidity effect model and Rotemberg and Woodford [1998] within a sticky price framework. Farmer [1999] has shown, real indeterminacy is an explanation of the failure of standard econometric tools to detect the Lucas critique even in a linear framework. The main explanation for this result is that standard cross–equation restrictions used to test for the Lucas critique (see Favero and Hendry [1992]) do not hold in models that give rise to real indeterminacy. The basic explanation for this result is that, since the model is backward looking, the agents do not need to exploit the information contained in the policy rule to form expectations, and nothing can be learned on the private decision rules from the form of the monetary policy. It must however be emphasized that most of the existing studies rely on a local analysis within a (log–)linear framework — *i.e.* with constant parameters — such that the latter assertion should be handled with much caution as the coefficients vary along the business cycle in our framework. For instance, the monetary policy has experienced higher volatility, as far as elasticities are concerned, in the US compared to Europe, as the volatility of γ_t is 3 times higher in the US than in France and Germany. This remains true if we now compare this volatility to that of the output gap that summarizes the state of the business cycle (relative standard deviation in table 2). From that respect France and Germany are quite similar, which was expected as the Bank of France is known to follow closely the Buba. Nevertheless, France displays bit higher relative volatility along the business cycle.

Another interesting feature that can be drawn from figure 4 is that central banks of all countries of the sample have had a tendency to increase their degree of reaction to inflation deviations within sharp recessions, and to decrease it along expansions. This is illustrated by the existing negative correlation between γ_t and the output gap.[6] Therefore, bad times are viewed as good periods for central bankers to act more severely due to the decrease in the inflation rate. Recessions are usually perceived, by central bankers,

[6]Correlations should however be interpreted with caution in this setting as the actual linking function between the output gap and the reaction parameter to the inflation rate is non–linear, whereas correlations are linear indicators. The magnitude of the correlation may thus lead to spurious interpretations and should not thus be taken too much seriously.

Table 2: Elasticities properties

	USA	Germany	France
$E(\gamma_t)$	3.0086	0.8941	1.2776
$\sigma(\gamma_t)$	1.6161	0.5522	0.4690
$\sigma(\gamma_t)/\sigma(x_{t-d})$	0.6609	0.2041	0.2351
$\rho(\gamma_t, x_{t-d})$	-0.8747	-0.9111	-0.8630
$E(\beta_t)$	-0.8276	0.3935	0.2288
$\sigma(\beta_t)$	0.2189	0.2478	0.4814
$\sigma(\beta_t)/\sigma(x_{t-d})$	0.0895	0.0916	0.2413
$\rho(\beta_t, x_{t-d})$	0.8747	0.9111	0.8630

as deflationary times as long as demand shocks dominate the explanation of the business cycle — at least in the short–run. In others, recessions are identified as situations in which inflation expectations are below the target. Then, the standard Fisher equation implies that the real interest rate increases, thus reinforcing the recession. Monetary authorities are thus willing to decrease the nominal interest rate in order to counter pressures to recession. This can be more easily achieved rising the elasticity of the reaction parameter to the inflation gap, thus stimulating investment and output. On the contrary good times do not yield high γ_t, implying that central bankers do not want to intervene too much but just try to stabilize inflation fluctuations to prevent the real interest rate from declining too sharply and thus throwing the economy into a "surchauffe". But it should also be noted that the form of the non–linearity constrains the reaction of central bankers to such deviations. This is particularly pronounced in France where it can be seen from figure 4 that the Bank of France did not raise its reaction to inflation deviations above 1.8 neither did it lower it below 0.8. In others, there exists an upper and a lower bound to inflation rate targeting in France. This is, by construction, also true in Germany but seems to be less pronounced. This actually reveals the external constraint that France faced within the period: the European Monetary System that put some pressure on the French monetary authorities to follow the German monetary policy. The US are also constrained, as revealed in the 1983 and 1992 recessions.

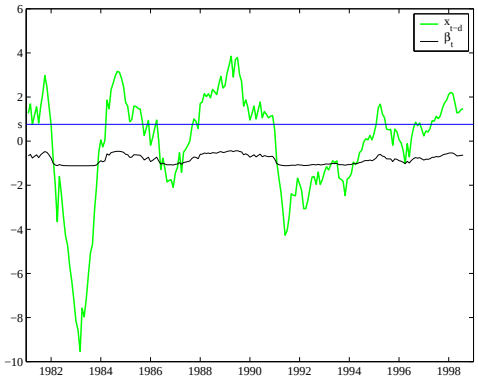
Similar conclusions can be drawn concerning the reaction to the output gap parameter. As can be seen from figure (5), β_t has varied along the BC over the whole sample, even if it displays much less variability than the reaction to inflation deviations. Contrary to the reaction to the inflation gap, it seems that there exists a significant difference between the US and the European monetary policy. The US monetary authorities seem to accommodate output fluctuations rather than trying to stabilize, as the mean of β_t is negative, implying that the FED decreases the nominal interest rate within expansions, thus reinforcing the expansionary pressures. This might seem rather surprising, unless one recognizes that US output is mainly explained by supply side phenomena. For instance, following a positive supply shock output raises but inflation decreases, implying that the real interest rate increases. Then if one is willing to stabilize expansion, in order to refrain inflationary pressures, the nominal interest rate has to decrease, which corresponds to a negative sign for β_t.

The opposite is true in Europe, and particularly for the French monetary authorities that seem to pursue a stabilizing policy, as the percentage of the overall volatility of the European business cycle explained by demand side phenomena is larger. However, the reaction parameter is far more volatile in France than in the two other countries, implying that France has experimented both accommodation and stabilization within the period. For instance, the volatility of β_t in France is about 50% that of the business cycle whereas this relative volatility is only 10% in Germany and in the US. Interestingly, the correlation between the reaction of the central bank to the output gap and the output gap is positive in all three countries.[7] In others, central banks have had a tendency to increase the degree of correction of output gap within expansions relative to recessions. This however has different implications depending on the side of the Atlantic. In the US, the evolution of β_t acknowledges that expansions are less "accommodated" than recessions. But as aforementioned this actually means a higher stabilization within a supply side economy. Therefore, the FED has a tendency to be more active in bad times than in good times and attempts to prevent the

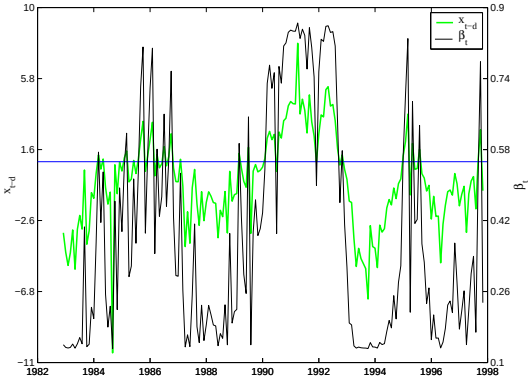
[7] As before, we do not comment on the magnitude of this correlation in order to avoid spurious interpretations.

Figure 5: Output gap targeting (β_t)

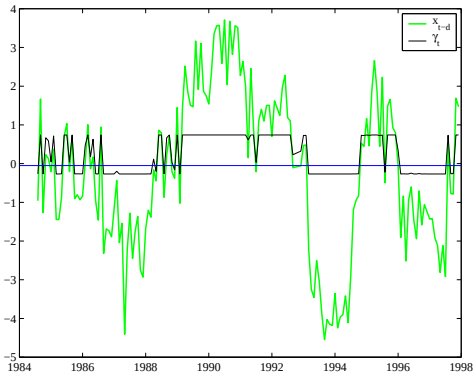
USA



Germany



France



economy to experience higher inflation in face of negative supply shocks. Things are different in France and Germany. Germany adopts a stabilizing policy in face of output gap fluctuations. It then appears that Germany is less willing to smooth recessions than expansions. This can be understood as the Buba is known to care for high inflation. Then if output gap fluctuations are mainly driven by demand shocks — as several studies seem to indicate — expansions are perceived by central bankers as announcing higher inflation. The Buba then increases its reactivity to the output gap. France has finally a very typical shape as expansions are stabilized whereas recessions are accommodated. Nevertheless, accommodation is less pronounced than stabilization in France, for which the threshold effect seems to be much more marked than in the two other countries.

Beyond the possibility of indeterminacy that we already mentioned, such non–linearities have other important implications in terms of quantitative relevance of the Lucas critique. In fact, in face of such a result, standard econometric analysis provides no relevant information to tackle the Lucas critique. Indeed, if we are to take the model seriously and consider it to be the true Data Generating Process, the coefficients of the nominal interest rule vary across time. Assume now that structural changes tests are conducted on a misspecified linear model for the announced nominal interest rate of the form retained by Clarida et al. [1998]:

$$i_t^\star = \alpha + \gamma(E_t\pi_{t+k} - \pi^\star) + \beta E_t x_{t+j} \text{ with } k, j > 0 \tag{8}$$

then standard tests would lead any econometrician to find support for a structural change in the form of the rule, as γ and β would be found to shift across different sub–samples. However, standard tests would not necessarily detect the Lucas critique since the true Data Generating Process would not have changed across sub–samples, as the deep parameters of the non–linear rule, the economic agents know, have not changed.

Another implication of the non–linearity in the policy rule is that what is usually identified with a structural break may not result from a change in the policy rule itself but rather from a modification in the business cycle features. In others, even if the policy rule (8) seems to change, this may

actually only reflect a change in the form of the business cycle due to the internal dynamics of the model. In that case, agents behavior should not be affected at all. This is actually a sign of a misspecified rule rather than a sign of any quantitative irrelevance of the Lucas critique.

Finally, it should be also noted that in some cases, the form of non–linearity we have assumed may yield some strong identification problems. Nonlinearities in policy rules may indeed result in an observational equivalence property: changes in the structural parameters of the policy rule do not necessarily involve a significant change in the outcome of the policy rules. For instance, reversing the sign of θ, and inverting β_i's and γ_i's, $i = 0, 1$, leave the properties of the rule unaffected in the sense that the laws of motion for γ_t and β_t are not altered. In that case, the true rule has changed, but no change can be detected. Standard exogeneity tests then fail to detect the Lucas critique.

In others, omitting the possibility of nonlinear policy rules may provide an explanation for the observed "irrelevance" of the Lucas critique.

4 Concluding remarks

This paper has attempted to show that the possibility for non–linear monetary possibility rules cannot be rejected a priori and can be supported by the data. More precisely, it appears that at least for the US, France and Germany, Taylor type rules can be generalized to non–linear forms involving a STAR representation that yields a deterministically varying coefficients rule. Inflation targeting then appears to be negatively correlated to lagged output gap whereas output gap targeting is positively correlated.

An attractive feature of these non–linearities is that they can provide an explanation, although trivial, for the "quantitative irrelevance" of the Lucas critique. Indeed, most of the tests for the Lucas critique are conducted in a linear or linearized framework, which cannot account for non–linearities. Then, structural changes detected in the monetary policy rules may finally only reflect misspecification problems of the rule, in which case no behavioral changes should be expected. Further non–linearities may translate into an observational equivalence property, such that even a change in the deep

parameters of the rule does not yield any changes in private behaviors. In others, the quantitative irrelevance of the Lucas critique may finally reflects misspecification problems.

It should however be noted that much remains to be done. First of all, we only report one typical form of non–linearity, and a more systematic investigation of the possibility for non–linearities in policy rules should be undertaken in order to better understand central banks behaviors and try to characterize potential explanations for the empirical departures from the Lucas critique.

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