Intertemporal Coordination Failure and Monetary Policy

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ISSN  2282-2801  DEM Discussion Papers [online]
Università degli Studi di Trento

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Ronny Mazzocchi †

This version: November 2013

Abstract

The turn of century long period of sustained growth with low and stable inflation let the economic profession and the public opinion to think that the right theoretical foundation for macroeconomic policy had been found. However the Great Crisis of 2008 indicates a spectacular failure of this framework in dealing with sources of macroeconomic instability and providing policy advise. Financial instability is the new challenge for monetary policy. Most of the recent research indicates that financial crises follow prolonged unwinding of investment-saving imbalances which are not contemplated by the standard theoretical framework. This paper draws a dynamic model where investment-saving imbalances are allowed to develop. It introduces different types of feedback interest-rate rules in order to provide some preliminary indications for the conduct of monetary policy.

JEL Classification: E21, E22, E31, E32, E52

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*I wish to thank Roberto Tamborini, Hans-Michael Trautwein, Andrea Fracasso, Luigi Bonatti, Dirk H. Ehnts, Emiliano Santoro, Massimo Molinari and Francesco Saraceno for helpful discussions and comments.

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1 Introduction

Over the last three decades a variety of specific monetary policy proposals consistent with macroeconomic theoretical developments have been debated and implemented around the world. Much of the disarray reflected in earlier disputes between Monetarist and Keynesian economists has been resolved in the consensus model of monetary policy referred to as the New Neoclassical Synthesis or NNS (Goodfriend and King, 1998; Clarida et al., 1999; Blanchard, 2000). The consensus model incorporates New-Classical features such as intertemporal optimization, rational expectations and a real business cycles (RBC) core, together with Keynesian features such as monopolistically competitive firms, staggered nominal price setting, and a central role for monetary stabilization policy. The basic reference model basis is a simple two-equation model of the inflationary process consisting of an output equation derived from households’ optimal lifetime consumption and an expectations augmented Phillips equation for inflation. Even when a larger model of the economy is employed - such as the version with the endogenous determination of the capital stock (Woodford, 2003; ch. 5) - these two equations usually form its core.

One key question was how to incorporate rational expectations so as to estimate and simulate a model suitable for policy evaluation and optimization. In so doing Taylor (1979) showed the inefficiency of a discretionary monetary policy in terms of excess volatility of inflation and output and argued that the best strategy was to use monetary aggregates as a policy instrument. Based on the research of Sargent and Wallace (1975), many economists indeed believed that a monetary policy implemented with an adjustable short-term interest rate was in large part responsible for rising and volatile inflation. Only at the beginning of the 1980s McCallum (1981) was able to show that even a short-term interest rate could be used as the monetary policy instrument if it is part of a rule which provides a nominal anchor, so that the price level is determinate. Following this line Taylor (1993) developed his famous rule that became the most common way to model monetary policy in the last fifteen years. Thinking about monetary policy as interest-rate policy is one of the hallmarks of the NNS that made increasing interaction possible between academics and central bankers (Woodford, 2003). For about two decades macroeconomists have been able to tell policymakers that in order to achieve optimal results, they should design institutions that minimize the time-inconsistency problem by promoting a commitment to policy rules. Many countries have changed their institutional framework for monetary policymaking in an apparent recognition of this problem.

Two changes are especially evident in the practice of monetary policy. First, central banks have become more independent from political authori-
ties. This is a consequence of the pervasive theoretical and empirical research on the fact the independence helps to reduce inflation rates without any adverse consequences on output (Kydland and Prescott, 1977; Alesina and Summers, 1993). Second, central banks have begun to concentrate on price stability and inflation control. The slowly emerged consensus seemed to be that inflation targeting was the preferred policy option (Svensson, 2010).

By 2002, more than twenty countries have adopted monetary frameworks that emphasize inflation targeting (Truman, 2003): Canada, New Zealand, Britain and the Euro Area use such numeric targets, while this issue is still unresolved for the United States, with the district bank presidents and the Washington board members divided over whether to set a specific inflation target.

This view became the consensus view because it seemed to be successful. A long period of sustained growth with low and stable inflation led not only the economic profession but also the public opinion to think that the right theoretical foundations for macroeconomic policies had finally been found. However the Great Credit Crisis that has developed since 2007 indicates a spectacular failure of this framework in dealing with sources of macroeconomic instability and providing policy advice. Especially in the United States many observers have attributed large responsibility to monetary policy, primarily as a result of misbehavior by monetary authorities (Taylor, 2007; 2010; 2011). Less attention has been devoted instead to the unforeseen consequences of the prescriptions distilled from the NNS. Nevertheless in this second strand there is no agreement on where the problems are. For sure there is a large consensus that a critical element concerns the nexus between monetary policy and financial markets. The conventional wisdom on this link was that a monetary regime that produces aggregate price stability will, as a by-product, tend to promote stability of the financial system (Bordo et al., 2000). This view has been shaken by accruing evidence that deviations of investment from trend are fairly good predictors of boom-bust cycles over the medium run, but they are often associated with low and stable inflation (Borio and Lowe, 2002; Gerdesmeier et al., 2009). These symptoms were also clearly present in the two major shocks to the

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1One notion of what it means for an authority to be independent is that society faces large costs to dismiss the authority and replace it with another (Rogoff, 1985).

2The argument that the independence from political power is a necessary condition for monetary stability is, however, subject to some criticism. For example, Fodor (1994) shows that under the gold standard regime, governments had powerful pressure on central banks but, despite this, there was no inflation. This fact can be explained by the value that the political system attributed to monetary stability rather than by the supposed independence of the central bank.

3The distinction between controlling the price index rather than the rate of inflation is crucial. A commitment to the former would mean deflating after a supply shock to return the index to its previous level, while the latter entails adjusting to the long-term rate of growth of inflation.
Great Moderation era: the “New Economy” bubble in the late 1990s, and the house-market bubble leading to the banking crisis of 2007. In all these episodes monetary policy did not react preemptively.

As a matter of fact, the move of central banks away from control of monetary aggregates towards interest-rate management has placed monetary policy at the very core of the transmission mechanism between the real economy and financial markets as regulators of the investment-saving process (Leijonhufvud, 2007). Since Edgeworth, Wicksell and Keynes macroeconomists have known that unless the supply of base money is restrained, the overall supply of money and credit cannot be controlled. Remaining within the neo-Wicksellian framework of the NNS, it requires the central bank to keep its policy rate in line with the nominal value of the natural rate of interest, identified as a general equilibrium variable determined by “deep parameters” (household’s intertemporal marginal rate of substitution and marginal return to capital). In so doing the NNS relies on Wicksell’s idea of the natural rate being determined by the forces of productivity and thrift and, in equilibrium, being coincident with the marginal product of capital (Wicksell, 1898, p. 82). However, it is worth recalling that Wicksell moved from a view that is notably at variance with the NNS framework. He viewed the natural rate of interest not as a variable that can be observed by anyone in the system, but possibly as a “hidden attractor” of the system, where the latter is driven by agents reacting to observable market signals.

A substantial amount of empirical research testifies that central banks can hardly rely on correct information about the natural rate of interest. A fact that in turn challenges the reliability of the monetary-policy strategy based on interest-rate control and inflation targeting.

A second challenge is that the loss of control of investment-saving process may not necessarily translate into higher inflation in the goods market, but on other markets instead. Indeed recent episodes of over-investment, such as the U.S. "New Economy” bubble in the late 1990s and the housing and mortgages boom in the last few years, point out the missing inflation puzzle as a critical element in the picture. More generally, in a number of episodes as shown in particular by Borio and Lowe (2002) and Borio (2008), inflation forecasts may fail to react to investment-saving imbalances, which typically accrue during, and at the same time create conditions for, prolonged periods of low interest rates, brisk economic activity and stable prices.

The coexistence of an unsustainable investment-saving imbalances on one side, and low and declining inflation on the other can be explained by a large number of factors. Overall they tend to create a positive association between

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4I owe this point to Axel Leijonhufvud.

5Relevant factors could be the successful implementation of the stabilization programs after the 1970s, which anchored price expectations and lead to a significant reduction in inflation. This situation create a general optimism about the future economic prospectives, which can underpin a consumption and lending boom, often financed by inflow of foreign
favorable supply-side developments (which push down the prices) and asset price booms (easier access to external finance and optimistic assessment of risk). The combination of rising asset prices, strong economic growth and low inflation can lead to overly optimistic expectations about the future which could generate increases in asset and credit markets significantly beyond those justified by the original improvement in productivity. Yet, a self-reinforcing boom can emerge, with increases in asset prices supported by stronger demand and sustaining, at least for a while, the optimistic expectations. While the stronger demand can put upward pressure on inflation, this pressure can be masked by the improvement to the supply side of the economy. In this context, the missing inflation has probably played a role in driving monetary policy onto a wrong track (Borio and Lowe, 2002). Using the Taylor rule central banks discover whether their policy rates are too low or too high when the price level starts to rise or fall, and they can then adjust their rate accordingly. The problem is that this crucial feedback loop can be short-circuited by the surge of a investment-saving imbalances. The trouble with inflation targeting in present circumstances is that an almost constant inflation rate gives no information about whether the monetary policy is right or not. And a wrong monetary policy allows the financial imbalances to grow without end (Borio and Lowe, 2002; Borio, 2008; Borio and Disyatat, 2011).

In recent years different approaches have been pursued with respect to these limitations of the NNS framework. One tries to modify the optimal design of monetary policy in order to prevent - or at least to counteract - the surge of asset price bubbles that may feed over-investment (Christiano et al., 2010; Grossi and Tamborini, 2011). Other works investigate how to modify the standard NNS model by adding a monetary, banking or financial sector (Iacoviello, 2005; Goodfriend and McCallum, 2007; Canzoneri et al., 2008). The approach I will develop in this paper challenges the NNS apparatus for being unable to deal with the patterns of events that should be explained because it focuses only on states of the economy characterized by continuous intertemporal equilibrium. The main question to be addressed is whether and how an interest-rate rule is effective in stabilizing the economy in the event of investment-saving imbalances. Section [2] presents a dynamic model with investment-saving imbalances, focusing on the role of the interest-rate feedback rule. Section [3] explores the dynamic properties of the economic capital. Asset prices typically rise and reinforce the credit boom. Another key role could have been played by the credibility of the central bank’s commitment to price stability, by anchoring expectations and hence inducing greater stickiness in prices and wages, can alleviate the inflationary pressures normally associated with the unsustainable expansion of the aggregate demand.

\textsuperscript{6}In the United States the faster productivity growth and the shifts in the structure of the labour market were partly responsible for the low inflation of the late 1990s and the strength of many equity markets.
system with different interest-rate rules and establishes the properties of a stabilizing rule. Section [4] concludes.

2 The theoretical model

In this section I briefly present a dynamic model whereby it is possible to assess some basic issues concerning the macroeconomics of investment-saving imbalances (Mazzocchi, 2013a). It should be recalled that the model is dynamic not in the current sense of the path of continuous intertemporal equilibrium, but in the sense that it tracks the behavior of the system out-of-equilibrium in the transition from one steady-state to another. The model portrays a competitive, flex-price economy peopled by rational forward-looking agents, and the central bank as the single public policymaker.

Let us start with the economy in intertemporal general equilibrium characterized by a natural rate of output \( y^{SS} \) as determined by a given combination of tastes, technology and the relative value of real wage rate \( \omega^{SS} \) with respect to the natural rate of interest \( r^{SS} \). According to the standard DSGE methodology these variables may change over time due to random shocks to the underlying parameters. Nevertheless this feature is inessential for my purpose, thus for the sake of simplicity I assume that all the general equilibrium variables \( (y^{SS}; \omega^{SS}; r^{SS}) \) are constant. All agents and the central bank, however, operate under limited information in that they don’t know the value of \( r^{SS} \).

The central bank aims at controlling the general price level by announcing a target inflation \( \pi^* \) and pegging the nominal interest rate \( i_t \). The latter is the rate at which households and firms can exchange bonds representative of physical capital in the capital market. The central bank pegs the nominal interest rate by means of open market operations such that it clears any excess demand/supply of bonds at the pegged value \( i_t \). Demand and supply of bonds arise from, respectively, the optimal consumption-saving plan of households and the optimal capital demand of firms, given available information, their future expected inflation rate \( \pi^e_{t+1} \) and the observed market real interest rate \( r_{t+1} = i_t - \pi^e_{t+1} \). The expected inflation rate is for the time being taken as given. Intertemporal general equilibrium requires \( r_{t+1} = r^{SS} \) at all times, or \( i_t = i^{SS} + \pi^e_{t+1} \).

Our starting point is that the central bank may peg the wrong interest-rate level, i.e. \( i_t \neq i^{SS} + \pi^e_{t+1} \). Given such interest-rate gap at time \( t \), an investment-saving imbalance occurs in that households wish to save more \( (i_t > i^{SS} + \pi^e_{t+1}) \) or less \( (i_t < i^{SS} + \pi^e_{t+1}) \), while firms wish to invest less/more than at \( r^{SS} \). As dictated by the intertemporal Walras law, any investment-saving imbalance at time \( t \) implies a sequence of output demand-supply imbalances at all dates. In order to force investment-saving realignment and
market-clearing, a sequence of present and future output gaps $y_{t+n} \neq y^{SS}$ at all times $n = 0, 1, \ldots$ is necessary. The output dynamics triggered by the initial interest-rate gap can be represented in a single first-order log-linearized equation like the following:

$$y_{t+1} = y^{SS} + \rho(y_t - y^{SS}) - \alpha(i_t - \pi_{e_{t+1}} - r^{SS})$$  \hspace{1cm} (2.1)$$

where $\alpha$ is the feed-forward effect of the interest-rate gap as of $t$ on future output, and $\rho$ captures the persistence effect of the interest-rate gap on contemporaneous output. These two parameters should satisfy:

$$\alpha = \frac{a - \rho}{1 - a}$$

where $a$ is the capital income share.

This equation reflects the first key feature of investment-saving imbalances, namely the dependence of present and future output gaps on the initial interest-rate gap such that output dynamics displays both autocorrelation and dependence on past interest-rate gap\(^7\). The steady-state of (2.1) is the output gap of the economy settles down after the initial interest-rate gap. There are several substantial differences in comparison with the traditional IS equation in the NNS model. Reading from the right to the left the equation shows the intertemporal feed-forward effect of interest-rate gaps. Reading from the left to the right, it generates time series of output gaps that, retrospectively, display dependence on the lagged value of the interest-rate gaps and some degree of spurious correlation measured by parameter $\rho$. Notably, a dynamic structure like (2.1) is consistent with recurrent empirical estimates of IS equations (Laubach and Williams, 2003; Caresma et al., 2005; Orphanides and Williams, 2002b; 2006). These empirical regularities are not easily accommodated in the NNS framework. Attempt to fix the problem usually amount to injecting additional “frictions” into the markets, or to postulating limits to the information-processing capacity of agents. Examples of inertial frictions can be found in Woodford (2003, ch. 5) and Aghion et al. (2004) whereas informational imperfections have been investigated by Mankiw and Reis (2003) and Sims (2003). The consideration of investment-saving imbalances may be seen as a more straightforward approach to serial correlation.

Parallely, in order to accommodate output gaps, the inflation rate at any point in time cannot be at the rate $\pi_{e_{t+1}}$ expected by agents. In fact, given this expectation embedded into nominal wage contracts, some “surprise inflation” is necessary for competitive firms to supply more or less output than

\(^7\)Recall that in the standard New-Keynesian IS equation, the output gap at each time depends on the contemporaneous interest-rate gap, and autocorrelation obtains only if ad hoc additional frictions are added.
The log-linear equation that represents the inflation path is:

$$\pi_{t+1} = \pi_{t+1}^e + \kappa(y_{t+1} - y^{SS}) + \upsilon(i_t - \pi_{t+1}^e - r^{SS}) \quad (2.2)$$

where \(\kappa\) denotes the link between output and inflation while \(\upsilon\) represents the elasticity of the inflation rate to change of the interest rate. It will be recalled that this latter parameter is the second key feature of the investment-saving imbalance model. In the presence of non-zero interest-rate gap in (2.2) the capital stock actually changes with respect to \(K^{SS}\). This modifies production capacity and output supply. If say \(i_t < r^{SS} + \pi_{t+1}^e\), excess investment and aggregate demand is generated in the economy at time \(t\), but excess capacity is generate at time \(t + 1\), which exerts downward pressure on inflation.

Finally, the model is closed by the determination of the expected inflation rate. It is useful to assume that agents form their inflation expectations at each point in time by striking a balance between the information they have about next realization of inflation \(E_t \pi_{t+1}\) and the target announced by the central bank \(\pi^*\) (Mazzocchi, 2013a). A consistent representation is the following:

$$\pi_{t+1}^e = \xi \pi_{t+1} + (1 - \xi) \pi^* \quad (2.3)$$

The parameter \(1 - \xi\) can also be interpreted as a degree of credibility of the central bank\(^9\).

The model composed by equations (2.1), (2.2) and (2.3) form a system of two first-order difference equations with two endogenous variables \([y_t; \pi_t]\), one time-varying exogenous variable \(i_t\) and three constant exogenous \([y^{SS}; \pi^*; r^{SS}]\). The system can conveniently be transformed in terms of two endogenous gaps \([\hat{y}_t \equiv y_t - y^{SS}; \hat{\pi}_t \equiv \pi_t - \pi^*]\) and one exogenous gap \(\hat{i}_t = i_t - i^{SS} = i_t - \pi^* - r^{SS}\):

$$\hat{y}_{t+1} = \rho \hat{y}_t - \alpha \hat{\pi}_{t+1} + \alpha \xi \hat{\pi}_{t+1}$$

$$\hat{\pi}_{t+1} = \frac{\kappa}{1 - \xi(1 - \upsilon)} \hat{y}_{t+1} + \frac{\upsilon}{1 - \xi(1 - \upsilon)} \hat{i}_t$$

\(^8\)When \(y_t > y^{SS}\) excess inflation is necessary in order to lower the actual real wage below \(\omega^{SS}\), while the opposite is necessary if \(y_t < y^{SS}\).

\(^9\)Equation (2.3) can be the result of a problem of cost minimization. Agents may have two strategies to choose from and the switching between the two would depend on the costs of sustaining the long-run expectations \(\pi^*\) as compared to the information costs of forming the short-run rational expectations \(E_t \pi_{t+1}\). The first cost could be represented as the cost \(\Delta_1\) of having an inflation expectation other than \(E_t \pi_{t+1}\), while the second can be interpreted as the cost \(\Delta_2\) of hot adjusting expectation with respect to long-term one \(\pi^*\). Therefore in each period \(t\) agents faces the following cost function:

$$M_t = \Delta_1 (\pi_{t+1}^e - E_t \pi_{t+1})^2 + \Delta_2 (\pi_{t+1}^e - \pi^*)^2 \quad (2.4)$$

Minimizing with respect to \(\pi_{t+1}^e\) and setting \(\xi = \frac{\Delta_1}{\Delta_1 + \Delta_2}\) we get exactly (2.3).
Setting:

\[ \alpha' = \alpha \frac{1 - \xi}{1 - \xi(1 + \alpha \kappa - v)} \]
\[ v' = \frac{v}{1 - \xi(1 - v)} \]
\[ \rho' = \rho \frac{1 - \xi(1 - v)}{1 - \xi(1 + \alpha \kappa - v)} \]
\[ \kappa' = \frac{\kappa}{1 - \xi(1 - v)} \]

we get, in matrix form:

\[
\begin{bmatrix}
\hat{y}_{t+1} \\
\hat{\pi}_{t+1}
\end{bmatrix} = \begin{bmatrix}
\rho' & 0 \\
\kappa' \rho' & 0
\end{bmatrix} \begin{bmatrix}
\hat{y}_t \\
\hat{\pi}_t
\end{bmatrix} + \begin{bmatrix}
\frac{-\alpha'}{\rho'} \\
\frac{\kappa' \alpha'}{\rho'}
\end{bmatrix} \hat{i}_t
\]

This model can be interpreted as a means to check the role of the natural rate as “hidden attractor”, that is whether the system is able to find a path that is consistent with the intertemporal general equilibrium steady-state. Clearly the system achieves the steady-state with zero endogenous gaps only if \( \hat{i}_t = 0 \). In other words, the system is unable to converge to the intertemporal general equilibrium as long as the initial interest-rate gap is not closed.

In fact, for any initial value \( \hat{i}_t = \hat{i}_{t-1} = \hat{i}_0 \neq 0 \), the system possesses the following steady state solutions:

\[ \hat{y} = -\left( \frac{\alpha'}{1 - \rho'} \right) \hat{i}_0 \quad (2.6) \]
\[ \hat{\pi} = \left( \frac{v' - \kappa' \alpha'}{1 - \rho'} \right) \hat{i}_0 \quad (2.7) \]

These model solutions highlight that, even in a frictionless economy, a cumulative process unfolds on the real side as well as on the nominal side of the economy. It is important to note that the extent of the output gap is independent of the responsiveness of inflation to the output gap itself (parameter \( \kappa' \)), that is, is independent of the degree of price flexibility\(^{10}\). The only reason why this feature may be relevant is through its interplay with the interest-rate gap via expected inflation. Indeed, as agents anticipate higher/lower inflation, the market real interest rate \( r_t = i_t - E_t \pi_{t+1} \) is reduced further with respect to the natural rate, increasing the gap and so are the output and inflation gaps along the adjustment path. This can be seen looking at the model. If \( \xi \) increases, both the coefficient of \( \hat{y} \) and \( \hat{\pi} \) in equations (2.6)-(2.7) tend to become larger: short-run rational expectations

\(^{10}\) As Keynes argued quite clearly, inflation/deflation per se cannot be the solution to the problem originating from a saving-investment imbalance as long as the interest-rate gap is not closed. Notably, this was the same conclusion, as far as the price level was concerned, reached by Wicksell in his critique of the limitations of the classical quantity theory of money, (Wicksell, 1898, p. 80).
amplify the gap between the steady-state and the intertemporal equilibrium path.

Let me say a few words on the sign of the two gaps. If $\hat{i}_0 < 0$, we will have a positive output gap $\hat{y} > 0$ while the sign of inflation gap $\hat{\pi}$ is ambiguous. If the elasticity of the capital stock to the interest rate is very high, a negative interest-rate gap will determine a big increase of the capital stock. Accordingly the AS curve will move much more than the AD and the dynamics will conclude with a positive inflation gap. Conversely, if the reactivity of the capital stock to the interest rate is low - as empirical evidence seems to suggest - the AS will move slightly and the system will end with a negative inflation gap. In both cases the co-movements of the two curves lead to a pronounced change in the output gap without causing appreciable inflation gaps (Greenwald and Stiglitz, 1987). This conclusion significantly alters certain policy provisions provided by the NNS.

3 Dynamic Properties under different interest-rate rules

So far the nominal interest rate gap has been treated as an exogenous variable. The thrust of the investment-saving imbalance model is that, as a result, the system will never return to its intertemporal general equilibrium path. The next step is to close the model with an adjustment equation of the nominal interest rate $i_t$ that endogenizes the dynamics of the interest rate gap after an initial shock. This was indeed Wicksell’s original intuition with his proposal to relate the policy rate to price dynamics. Technically speaking this operation transforms the system from non-homogenous to homogenous in that all three gaps now appear as endogenous variables with no exogenous variables. In general, one expects homogenous systems to have zero-gap solutions in steady state, which is in fact the end state of the economy we are looking for.

Of course, there are various possible ways to accomplish this task. In the NNS the model is closed by a monetary policy equation that describes the reaction function of the policymakers in terms of a Taylor rule. The latter implies that the instrumental rate is anchored to the real interest rate that prevails when all macroeconomic state variables are at their target values. Theoretical as well as empirical research suggested that this kind of feedback rule supports a determinate rational-expectation equilibrium.

\[11\] This result seems to run contrary to the standard macroeconomics model used nowadays. In any case we should note a coincidence in the sign of the interest-rate gap and the inflation gap also in Casares and McCallum (2000) and in Ellison and Scott (2000).

\[12\] Of course, the adjustment path may consider also the delays due to time lag and/or adjustment costs of capital. This variation on the theme will not be developed here, given that it qualitatively share the same dynamic properties that I am going to study for my formulation.
(Blanchard and Kahn, 1980) provided that they embody the so-called Taylor principle, namely that the elasticity of the interest rate to excess inflation should be greater than one. The Taylor principle also implies that excess inflation arises whenever the instrumental interest rate is below the level consistent with the natural rate, while curbing excess inflation requires the instrumental interest rate to be set above the level dictated by the natural rate. Nevertheless, if we abandon the continuous intertemporal equilibrium hypothesis embodied by the NNS and we move toward an investment-saving framework, there emerge significant differences. Therefore I shall explore different ways to introduce monetary policy and their different implications for the sake of dynamic control and stabilization of the investment-saving imbalances processes. The question to be addressed is whether this approach to monetary policy is effective in stabilizing the economy if the possibility of intertemporal coordination failure is introduced.

3.1 The non-optimality of the optimal Taylor rule

3.1.1 The optimal Taylor rule

In the NNS increasing emphasis has been placed on the design of optimal monetary policy rules with reference to the welfare benchmark of the economy. In spite of the flavour of formal rigour of this procedure, results are flimsy and inconclusive due to the unresolved issue of the choice of the appropriate welfare function and its correct specification. In most of the cases, the interest-rate reaction function is derived from an optimal control problem of the central bank like the following (Clarida et al., 1999; Woodford, 2003):

$$\min L_t = -\sum_{s=0}^{\infty} \frac{1}{2} \left[ \eta_\pi (\pi_t + s - \pi^*)^2 + \eta_y (y_t + s - y^{SS})^2 \right]$$

subject to:

$$\pi_t - \pi^* = \kappa'(y_t - y^{SS}) + v'(i_t - i^{SS})$$

The central bank aims at minimizing the absolute value of the square gaps from steady-state values of relevant variables along the dynamic path of the system, where $\eta_\pi$ and $\eta_y$ measures the weight assigned to each variable. Using this formulation, we shall see that if $\eta_\pi = 1$ and $\eta_y = 0$ the policy regime is a pure inflation targeting, while if $\eta_\pi > 1$ and $\eta_y > 0$ it is a flexible inflation targeting, indicating that the central bank can give weight to gaps of other variables in addition to inflation, namely output (Svensson, 1997). Furthermore, if $\eta_\pi > \eta_y$, the central bank gives greater weight to inflation than output and is therefore called ”conservative” (Rogoff, 1985). By applying the same procedure as Clarida et al. (1999) we obtain an ”optimizing” Taylor rule:

$$i_t = i^{SS} + \gamma_y (y_t - y^{SS}) + \gamma_\pi (E_t \pi_{t+1} | i_{t-1} - \pi^*)$$

12
where 

\[ \gamma_y = \frac{\eta_y \rho'}{\alpha'} \quad \text{and} \quad \gamma_\pi = \frac{\eta_\pi \kappa'}{\alpha'} \]

This formulation includes three targets \( (y^{SS}, i^{SS}, \pi^*) \). The first two imply that the central bank has the complete information about the economy about the true structural relationships among the relevant variables and the true state of them at each point in time. This rule presents some important features. First, there is an explicit target for the interest rate, namely the natural rate of interest \( i^{SS} \), as the intercept of the equation. Second, the informational inflation rate used to assess the cyclical position of the economy is not current inflation, but \( E_t \pi_{t+1} | i_{t-1} \), i.e. the forecast of the inflation rate in absence of policy interventions (Woodford, 2003, ch.8). Third, the coefficients \( \gamma_y \) and \( \gamma_\pi \) are not arbitrary, but are determined by the central bank’s loss function and by the structural parameters of the economy.

Let me first examine the dynamic properties of the economy under equation (3.2). If we shift the term \( i^{SS} \) to the left-hand-side, use the structural model to solve for \( E_t \pi_{t+1} | i_{t-1} \), and move one period forward, we obtain equation (3.2) in gap terms. Together with equations (2.5), if forms a homogenous system in three gaps \([\hat{y}_{t+1}; \hat{\pi}_{t+1}; \hat{i}_{t+1}] \) for which a steady state solution with zero gaps exists.

\[
\begin{bmatrix}
\hat{y}_{t+1} \\
\hat{\pi}_{t+1} \\
\hat{i}_{t+1}
\end{bmatrix} = A \cdot 
\begin{bmatrix}
\hat{y}_t \\
\hat{\pi}_t \\
\hat{i}_t
\end{bmatrix}
\]

(3.3)

where:

\[
A = 
\begin{bmatrix}
\rho' & 0 & -\alpha' \\
\rho' \kappa' & 0 & \nu' - \alpha' \kappa' \\
\rho' [\gamma_\pi \kappa' \rho' + \gamma_y] & 0 & \gamma_\pi \nu' - \alpha' [\gamma_\pi \kappa (1 + \rho') + \gamma_y]
\end{bmatrix}
\]

Hence the system supports a rational-expectations equilibrium in the target inflation rate \( \pi^* \) set by the central bank: this solves the problem of coordinating inflation expectations in the economy. Actually, the optimal interest-rate rule gives the central bank the right prescription and indicator in order to prevent investment-saving imbalances process: since the rule is anchored to \( i^{SS} \) at any point in time, ceteris paribus it happens that \( \hat{i}_t = 0 \) in all \( t \), whatever the value of the natural rate, which implies \([\hat{y}_{t+1}; \hat{\pi}_{t+1}] = 0 \) in all \( t \). Therefore, the economy is constantly kept in the zero-gaps steady state and no imbalances would ever arise.

The success of many central banks at achieving low and stable inflation over the past decades led the economic profession to think that the previous conditions were the right theoretical and practical foundation for macroeconomic policies. The end of the Great Moderation Era has seriously shaken
this view. Until now a reliable tool-kit of indicators of inflationary pressures and other underlying economic imbalances has remained elusive. Although the obvious potential role the natural rates could play in the conduct of monetary policy, the fact that both cannot be observed draws into question its practical usefulness. Skepticism about the use of the natural rates for monetary policy was largely prevailing in the past. Wicksell himself thought that the natural rate is inherently unobservable and would be difficult to measure in practice (Wicksell, 1898). Keynes was even more radical, casting doubts on the existence itself of a single general equilibrium real rate of interest (Keynes, 1937). Friedman still made the point when he linked the natural rate of unemployment to the natural rate of interest in his Presidential Adress (Friedman, 1968, p. 8), but he also warned that attempts at conducting monetary policy with reference to natural rates might be fallacious. Indeed targeting a gap variable required estimation of the unobserved natural rates of interest, output, or unemployment. In principle, this is subject to bias because “it is almost impossible to define full employment in a way that is logically precise” (Friedman, 1963, p. 40). In practice, it had resulted in “unduly ambitious targets of full employment” (Friedman and Friedman, 1980, p. 311). There are clear links between these positions and the work of Orphanides (2003) on the danger of relying on real-time measures of the output gap when formulating policy. Doubts concerning the practical use of natural rates for monetary policy are now mounting again (Garnier and Wilhelmsen, 2005; Gnan and Ritzberger-Gruenwald, 2005; Amato, 2005).

Even if we neglect these criticism on the opportunity to use the natural rates, there is the undue neglect of central banks’ problems with information about both variables. Their estimations are not straightforward and are associated with a very high degree of uncertainty (see also Hauptmeier et al., 2009; Clark and Kozicki, 2005; Laubach and Williams, 2003; Caresma et al., 2005). A growing literature shows that wrong information might seriously destabilize the system (see Orphanides and Williams, 2002b, 2002a, 2006; Primiceri, 2006). The common view of these models is that poor stabilization performance may be due not to the lack of the “right” rule but to the lack of the “right” information about that rule. Moreover, the risk of this information deficiency is not only the worsening of the stabilization performance, but the driving of the economy on an altogether non-convergent path. In fact, as seen in the previous sub-section, the Taylor rule works as it transform a non-homogenous system into a homogeneous one. In other words, it works if the interest-rate target is always equal to the “true” natural rate of interest and the output gap target is always equal to the natural rate of output. Any discrepancy between the two implies a non-zero-gaps steady state for the whole system.

Let us go back to our initial assumption that the central bank has no exact information about the natural rates and let $i^{SS}$ and $y^{SS}$ be replaced by $\tilde{i}$ and $\tilde{y}$ respectively. Then define $\tilde{i} = \tilde{i} - i^{SS}$ and $\tilde{y} = \tilde{y} - y^{SS}$. The
system that is obtained in this case is:

\[
\begin{bmatrix}
\hat{y}_{t+1} \\
\hat{\pi}_{t+1} \\
\hat{i}_{t+1}
\end{bmatrix} = A \cdot 
\begin{bmatrix}
\hat{y}_t \\
\hat{\pi}_t \\
\hat{i}_t
\end{bmatrix} + \begin{bmatrix}
0 \\
0 \\
1
\end{bmatrix} \hat{i} + \begin{bmatrix}
0 \\
0 \\
-\gamma \eta_y
\end{bmatrix} \bar{y}
\] (3.4)

Hence the system cannot achieve a zero-gap steady-state as long as \((\bar{i}, \bar{y}) \neq 0\) (the situation is similar to that in section [2], with an exogenously pegged interest rate). This result exemplifies that the central bank may fail not because it follows the wrong rule but because it uses the wrong information.

### 3.1.2 Lagged Information

Theoretically, under suitable learning rules and appropriate stochastic processes, the central bank can learn the true value of the natural rates and updating the rule in real time, with the process converging towards a “self-confirming” equilibrium which generates optimal policy responses (Sims, 1998; Sargent, 1999). Therefore let me assume a simple error correction mechanism (Orphanides and Williams, 2002b):

\[
\tilde{x}_t - x^{SS} = (1 - \tau_x)(\tilde{x}_{t-1} - x^{SS}) \quad x = i, y
\]

where \(\tau_x \in [0, 1]\) measures the correction speed. With \(\tau_x = 1\) there is virtually no error in the natural rates used by the central bank, whereas \(\tau_x = 0\) yields a fixed constant error. Introducing this correction mechanism in the system (3.3) would add an exogenous process to the three endogenous gaps \([\hat{y}_{t+1}; \hat{\pi}_{t+1}; \hat{i}_{t+1}]\). The correction mechanism would directly affect the processes of \(\hat{i}_{t+1}\) and \(\hat{y}_{t+1}\). If the correction mechanism is convergent over time, the only possible effect is that the adjustment process of the whole system is slowed down but it is not disruptive. Although the details of the learning process are crucial, here I do not probe into them, but more straightforwardly I wish to address the question whether equation (3.2) is able to correct an initial, transitory, informational error of the central bank. Hence I wish to examine how the optimal rule works once the central bank has caught up with the true natural rates. To this effect, let me simply posit that the central bank can discover the true natural rates with one period lag after the relevant shock has occurred. Let me consider the case that the shock occurs at time 0, so that \(\tilde{x}_0 = \tilde{x}_0 - x^{SS}\) and \(\tilde{x}_t - x^{SS} = 0\) (with \(x = i, y\) for all \(t > 0\)). The dynamic process of the system is given by (3.3). As said above, this system admits a zero-gap steady-state solution \(x = 0\). To check for convergence note that by way of a chain of substitution into (3.3), we obtain:

\[
\hat{i}_{t+1} = \left(\kappa \left[\alpha' + \kappa' (1 + \rho') \right] (1 - a) - \kappa' \rho^2 \alpha' (1 - a) - \rho' \left[\alpha' + \kappa' (1 - a) \right] \eta_x - \rho' \left[\alpha' + \kappa' (1 - a) \right] \eta_y\right) \hat{i}_t
\]
This is a first-order autoregressive equation of the interest-rate gap. It is a useful formulation as it highlights the self-corrective nature of an interest-rate process provided that the coefficient of $\hat{i}_t$ is bounded between $[-1; 1]$. Yet, an endogenous interest-rate equation is a necessary, but not sufficient, condition for convergence to the zero-gap state of the economy.

**Proposition 1** Given the structural parameters $a$, $\alpha'$, $\rho'$, $\kappa'$, and $\nu'$, for the system to converge to, and to be stable around, the zero-gaps steady state, the parameters $\eta_\pi$ and $\eta_y$ should satisfy the following conditions:

$$\alpha(a - 1) < \Upsilon_1 \kappa' \eta_\pi - \Upsilon_2 \rho' \eta_y < \alpha'(1 - a)$$  \hspace{1cm} (3.5)

where:

$$\Upsilon_1 = (\nu' - \kappa' \alpha'(1 + \rho'))(1 - a) - \kappa' \rho'^2$$

$$\Upsilon_2 = [\rho' + \alpha'(1 - a)]$$

The proposition indicates that, in the event of lagged information of the central bank on changes in the natural rates, the optimal interest-rate rule may grant convergence to the zero-gap steady state, but this in turn requires that the central bank’s parameters are bounded. This is a general feature of the stability conditions for a model with intertemporal coordination failure: we can call it *boundedness principle* of the interest-rate rules. The difference between the NNS models - which have a lower bound - and this model - which instead presents both a lower and an upper bound - lies in microfoundations underlying the IS equation. While in our framework an interest-rate gap influences both the present and future output and inflation gaps, in those of the NNS it has only temporary effect, limited to the period when the shock occurs. As a consequence, in our framework, when the central bank raises/lowers the nominal interest rate in $t$, it generates a sequence of negative/positive impulses on output and inflation gaps in the subsequent periods too. Moreover, it is worth noting that, as can be gauged from condition (3.5) the boundedness principle is more stringent, the larger is parameter $\xi$, i.e. the closer is the economy to the ideal type of competitive market with rational expectations. The underlying idea is that, when these parameters are large, small interest-rate interventions induce large changes in output and inflation gaps. Therefore the stability of the system requires less sensitivity of monetary policy to gaps and gentle, rather than aggressive, interest-rate corrections are required. If we admit the possibility of investment-saving imbalances the stress on high responsiveness of the central bank to inflation is justified to the extent that prices and related expectations are sticky, so that inflation and output are not highly responsive to interest-rate gaps and inflation gaps would consequently persist for a long time.

The first important implication of Proposition 1 concerns one of the key elements of modern monetary theory, namely the so-called *Taylor Principle*. 

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The main contributions of the literature on this subject say that $\gamma_\pi$ should be greater than 1. The underlying idea is that when there is a positive inflation gap, the central bank should proceed to a more than proportional increase in the real interest rate. However Woodford (2003, p. 253-54) has shown that the Taylor principle should apply not only to the inflation coefficient, but to the whole reaction of the interest rate to the inflation gap. As we have seen, also in our model the output and inflation gap are mutually connected through the AS curve, then the reaction depends on both the inflation coefficient and the output coefficient. Knowing that $\hat{y}_t = \kappa^{t-1}(\hat{\pi}_t - \nu'\hat{i}_{t-1})$, simple algebraic manipulations of equation (3.3) yield:

$$\hat{i}_t = -\left\{\gamma_\pi \left[\nu'(\rho' - 1) + \kappa'\alpha'\right] + \gamma_y \kappa'\nu'\right\} \nu_{t-1} + (\gamma_\pi \rho' + \gamma_y \kappa'\nu')\nu_t$$

As mentioned above, the Taylor principle would require that the compound inflation coefficient satisfies:

$$\bar{\gamma}_\pi \equiv \gamma_\pi \rho' + \gamma_y \kappa'\nu' > 1$$

Upon substituting the appropriate expressions for $\gamma_\pi$ and $\gamma_y$ we get:

$$\eta_\pi \kappa'\nu^2 + \eta_y > \frac{\alpha'\kappa'}{\rho'}$$

(3.6)

Obviously, this last condition may not be consistent with Proposition 1. Two relevant cases are possible. If condition (3.6) is compatible with (3.5), the former is irrelevant for stability, otherwise it is incompatible with the stability of the system. The mechanical adoption of the Taylor principle has generated the belief that the larger is the inflation-aversion parameter $\eta_\pi$ the better it is. However, the intertemporal coordination failures are such that the interest-rate reaction to inflation gaps must be bounded.

The second consideration that we can make concerns the choice of parameters $\eta_\pi$ and $\eta_y$. As Clarida et al. (1999, p. 1668-69) pointed out, these parameters have no clear foundations and interpretations. Usually, they are meant to capture the relative importance of price and output stability respectively (Uhlig, 2001). In this view it seems that they can be a matter of taste. Nevertheless this explanation is grossly inaccurate. First, the choice of parameters must take into account the relationship between inflation and output. This relationship is far from being unique and depends on the reactions of each variables to interest rates gaps. If the reaction of capital stock is slight - namely $\nu$ is small - the inflation and output gaps are positively correlated. In this case stabilizing inflation also stabilizes output, and vice-versa: once the targets of inflation and output have been chosen consistently with the steady-state of the system, the loss function parameters co-determine the dynamic paths of both inflation and output gaps (Tamborini, 2010). Conversely, if the responsiveness of capital to the
interest rate is high - namely \( \upsilon \) is large - the inflation and output gaps are negatively correlated and the central bank faces conflicting objectives. In this case the choice of the policy parameters reflects the relative importance of one objective over the other. However, as we already have said, the co-movements of aggregate supply and demand curves determine small and ambiguous changes in the inflation gap and contemporary large variation of the output gap (Casares and McCallum, 2000). Thus, inflation appears to be not the best indicator on which to base a monetary policy. There is the possibility that the correction implemented by the central bank is insufficient or that the convergence dynamics of the real variables to the steady state is too slow. In some cases we can also observe a divergent dynamics of the system.

The choice on \( \eta_\pi \) and \( \eta_y \) should also take into account the second dynamic property of the system, namely the type of convergence. It is curious that this issue is virtually ignored by the NNS: in fact the type of convergence towards the steady-state is not indifferent. Of course, this is not the right place to discuss widely this issue. However, it is easy to see how oscillatory dynamics, although convergent, can produce a destabilization of the inflation expectations of agents, with deleterious effects on the whole economy. By contrast, a monotonic convergence, though not optimal from the standpoint of minimizing the welfare loss, could be more desirable. Let me analyze this point in the model. We can say that:

**Proposition 2** *Once the stability condition on the central bank’s parameters has been satisfied, the system can achieve monotonic convergence only if:*

\[
0 < \Upsilon_1 \rho' \eta_\pi - \Upsilon_2 \rho' \eta_y < \alpha'(1 - a) \tag{3.7}
\]

We shall see in the next sub-section that this condition is satisfied only in the case of long-run inflation expectations and sticky prices. Here I want to focus briefly on the oscillatory convergence. The reason for these dynamics is closely linked to the central bank’s behavior. If it delays of changing the interest rate after the natural rates have changed, and it reacts first to the expected inflation gap, the rule dictates a reaction of both signals; hence, \( i_t \) will overshoot \( i^{SS} \) so that the former will take an oscillatory path.

Summing up, the exploration of the optimal interest-rate rule leads to quite problematic conclusions. The choice of the policy parameters cannot merely be a matter of taste but they should take into account the values of the parameters associated with structural variables, the inflation expectations of agents and the properties of the dynamic process. Despite the existence of a central bank with a detailed knowledge of the structural model of the economy, this approach could lead to choices which could be suboptimal or even disruptive for the system.
3.1.3 A quantitative assessment

Having clarified the general stability requirements of the optimal interest-rate rule in the event of investment-saving imbalances, the details discussed above are essentially empirical in nature. Since it may be of some interest to grasp the quantitative dimension of the issues involved, I now present a simulation of the system composed by equations (2.5) and (3.3). Selected estimates of parameters are taken from the leading NNS literature and are organized in Table 1.

I shall focus on two critical parameters that characterize the economic structure: the extent of short-term rational expectations measured by $\xi$ and the degree of price flexibility reflected by $\kappa$. Thus, our parameter grid can eventually be generated by two extreme cases: the first corresponds to the New-Neoclassical paradigm (NCM) of perfect flexible prices and short-run rational expectations ($\kappa = 0.7$, $\xi = 0.9$)\(^{13}\), whereas the second approximates an economy closer to the Old Neoclassical Synthesis (ONS) with sticky prices and static long-run expectations ($\kappa = 0.1$, $\xi = 0$). All the possible combinations are summarized in Table 2.

Since a conservative central bank is now regarded as the normative benchmark, I wish to consider a specific loss functions of central bank where $\eta_{\pi} = 1$. My first step is to use condition (3.5) to determine the upper bound of the output-gap parameter $\eta_{y}$. The relevant figures are given in Table 3.

The first important message is that different combinations of parameters ($\kappa, \xi$) have remarkable impact on the conservative bank’s choice set for stability. The more the economy is closer to the NCM paradigm, the more the

\(^{13}\)Since $\xi = 1$ implies a discontinuity that prevents computable simulations, it will approximated by 0.9.

<table>
<thead>
<tr>
<th>Paper</th>
<th>$a$</th>
<th>$\alpha$</th>
<th>$\xi$</th>
<th>$\omega$</th>
<th>$\rho$</th>
<th>$\kappa$ (sticky)</th>
<th>$\kappa$ (flex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laubach - Williams (2003)</td>
<td>0.10</td>
<td>-</td>
<td>-</td>
<td>0.45</td>
<td>0.05</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Garnier - Wilhelmsen (2005)</td>
<td>0.18</td>
<td>-</td>
<td>-</td>
<td>0.45</td>
<td>0.10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Rotemberg - Woodford (1997)</td>
<td>0.16</td>
<td>-</td>
<td>-</td>
<td>0.40</td>
<td>0.02</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Orphanides - Williams (2002)</td>
<td>0.02</td>
<td>0.50</td>
<td>-</td>
<td>0.47</td>
<td>0.14</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>McCallum - Casares (2000)</td>
<td>0.21</td>
<td>-</td>
<td>0.13</td>
<td>0.38</td>
<td>0.11</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Tamborini (2010)</td>
<td>0.40</td>
<td>0.15</td>
<td>0.50</td>
<td>0.33</td>
<td>0.10</td>
<td>0.67</td>
<td>-</td>
</tr>
<tr>
<td>This Model</td>
<td>0.40</td>
<td>0.20</td>
<td>0.50</td>
<td>0.10</td>
<td>0.40</td>
<td>0.10</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Table 1 Available estimates of the model’s parameters
Table 2 Parameters grid

<table>
<thead>
<tr>
<th>Weight of short-term rational expectations</th>
<th>Sticky-price parametrization $\kappa=0.1$</th>
<th>Intermediate-case parametrization $\kappa=0.4$</th>
<th>Flex-price parametrization $\kappa=0.7$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\xi=0$</td>
<td>$\alpha'=0.20$ $\beta'=0.40$ $\gamma'=0.10$ $\kappa'=0.10$</td>
<td>$\alpha'=0.20$ $\beta'=0.40$ $\gamma'=0.10$</td>
<td>$\alpha'=0.20$ $\beta'=0.40$ $\gamma'=0.10$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\alpha'=0.20$ $\beta'=0.43$ $\gamma'=0.18$ $\kappa'=0.73$</td>
<td></td>
</tr>
<tr>
<td>$\xi=0.5$</td>
<td>$\alpha'=0.19$ $\beta'=0.41$ $\gamma'=0.18$ $\kappa'=0.18$</td>
<td>$\alpha'=0.20$ $\beta'=0.43$ $\gamma'=0.18$</td>
<td>$\alpha'=0.21$ $\beta'=0.46$ $\gamma'=1.27$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\alpha'=0.17$ $\beta'=0.64$ $\gamma'=0.53$ $\kappa'=2.11$</td>
<td></td>
</tr>
<tr>
<td>$\xi=0.9$</td>
<td>$\alpha'=0.12$ $\beta'=0.44$ $\gamma'=0.53$ $\kappa'=0.53$</td>
<td>$\alpha'=0.17$ $\beta'=0.64$ $\gamma'=0.53$</td>
<td>$\alpha'=0.31$ $\beta'=1.19$ $\gamma'=3.68$</td>
</tr>
</tbody>
</table>

Table 3 Optimal rule of the conservative central bank ($\eta_{\pi} = 1$). Values of the stability upper bound of $\eta_{\pi}$, and the implied values of the interest-rate rule coefficients.
central bank should be conservative (low value of $\eta_y$), but less governable the system becomes.

The figures in cells ($\kappa = 0.4, \xi = 0.9$),($\kappa = 0.7, \xi = 0.9$) indeed have little economic meaning. They imply that even setting $\eta_y = 0$ (or even negative), a pure inflation targeting strategy would not achieve stability. The central bank also ought to reduce its inflation-aversion parameter. For example, the configurations ($\kappa = 0.7, \xi = 0.5, \eta_y = 0$) and ($\kappa = 0.7, \xi = 0.9, \eta_y = 0$) would require $\eta_\pi < 0.2$ and $\eta_\pi < 0.007$ respectively. To put it differently, contrary to the Taylor principle high values of ($\kappa, \xi$) require low values of the compound inflation coefficient $\gamma_\pi$ in the interest-rate rule.

To complete our quantitative assessment, let me provide in Figure 1-2-3 the simulations of the pure inflation targeting regime under the three configurations discussed above, namely the ONS case ($\kappa = 0.1, \xi = 0, \eta_\pi = 1, \eta_y = 0$) which is monotonically convergent, the intermediate case ($\kappa = 0.4, \xi = 0.5, \eta_\pi = 1, \eta_y = 0$) which is oscillatory convergent, and the NCM case ($\kappa = 0.7, \xi = 0.9, \eta_\pi = 1, \eta_y = 0$) which is explosive. As mentioned in Proposition 2 the dynamic process follows a monotonic path towards the equilibrium only when prices are almost sticky and agents’ expectations are anchored to a long run average value of inflation rate. In the remaining cases the system shows oscillatory convergence. This element, together with the boundedness principle, have direct bearing upon the actual magnitude of welfare losses as measured by the central bank’s loss function, with some peculiar effects that are at variance with common wisdom.

### 3.2 Adaptive rules

In the previous subsections we saw that the central bank may still be able to correct errors due to the imperfect information on the natural rates under the assumption that sooner or later the correct information becomes known. Nevertheless the idea that the central bank may eventually understand that the target set is wrong and that the economy displays permanent output and inflation gaps is not so obvious. In reality output and inflation are continuously hit by their own shocks so that it may not be so easy to detect that output and inflation are not on their intertemporal equilibrium path. Thus, the persistence of the error also makes rather impossible to switch off the rule or to take any correction. The estimates and the simulations presented by Primiceri (2006) suggests that, in the long run, a central bank has eventually been successful. However, in that paper the long run covers around fifteen years between the late 1960s and the early 1980s resulting in the so-called American “Great Inflation”. On the contrary, Orphanides and Williams (2002b) do not lend empirical support to the convergence prediction and assumes that errors in the natural rates measurement are persistent.

The informational requirements of the optimal interest-rate rule and the
related problems suggests to look for more robust rules that do not make use of “natural” variables and conversely employ only observed macroeconomic variables. As Orphanides and Williams (2002b) show, these rules may not match theoretical criteria of optimality, but allow for reliable stabilization policy. To address this issue, we may conveniently begin with a simple representation of an adaptive Taylor rule as the following:

\[ i_{t+1} = (1 - \gamma_i)i_t + \gamma(y_{t+1} - y_t) \] (3.8)

Let us express the rule in terms of gaps:

\[ \hat{i}_{t+1} = (1 - \gamma_i)\hat{i}_t + \gamma\hat{\pi}_{t+1} + \gamma y_{t+1} (\hat{y}_t - \hat{y}_t) \] (3.9)

This equation represents the hidden adjustment process ongoing in the economy, and now it is not implied that anyone knows it. Now equations (2.5) and (3.9) form the homogeneous system in three endogenous gaps \[ [\hat{y}_{t+1}, \hat{\pi}_{t+1}, \hat{i}_{t+1}] \] and, again, we can strip it down to a single autoregressive equation of the interest-rate gap:

\[ \hat{i}_{t+1} = \left(1 - \gamma_i + \frac{1 - \rho' - \alpha'(1 - a)}{1 - a} \gamma_y + \frac{(v' - \alpha' \kappa')(1 - a) - \rho' v'}{1 - a}\right)\hat{i}_t \]

Starting from any initial interest-rate gap \( \hat{i}_0 \neq 0 \), the economy is driven back to its intertemporal general equilibrium steady state provided that the interest rate gap process converge to zero or that the autoregressive coefficient falls within the unit circle. Yet, the dynamic properties of the system depend on the interplay between the parameters \( \gamma_i, \gamma_y, \gamma_y \). The following proposition holds:

**Proposition 3** With an adaptive interest-rate rule like (3.9), for the system to converge to the zero-gaps steady state, the policy coefficients should satisfy the following conditions:

\[ 2(a - 1) < \Upsilon_3 \gamma_y + \left[1 - \rho' - \alpha'(1 - a)\right]\gamma_y - (1 - a) \gamma_i < 0 \] (3.10)

where

\[ \Upsilon_3 = (v' - \alpha' \kappa')(1 - a) - \rho' v' \]

The first observation is that, also in the case of an adaptive monetary policy rule we find an upper bound condition on the interest-rate rule coefficients \( \gamma_i, \gamma_y \) and \( \gamma_y \). As we noticed above, this is due to the microfoundations underlying the IS equation and the intertemporal coordination failure problem. As in the case with the optimal Taylor rule, stability depends on the compound effect of the three coefficients, not on their relative magnitude.

The second observation is that also in this case the system may admit monotonic as well as oscillatory convergence towards the steady-state. The following proposition holds:
Proposition 4 Monotonic convergence obtains up to a frontier of interest-rate rule coefficients given by the following condition:

\[(a - 1) < \Upsilon_3 \gamma_\pi + [1 - \rho' - \alpha'(1 - a)]\gamma_y - (1 - a)\gamma_i < 0 \quad (3.11)\]

For the reasons discussed in the previous section, monotonic convergence may be an attractive feature for policymakers and, in general, it is interesting to compare the dynamic properties of the two regimes. For concreteness Table 4 contains the monotonic/oscillatory upper bounds of coefficients $\gamma_\pi$ and $\gamma_y$, according to Proposition 4 and with our usual parametrization grid. As can be seen, an adaptive rule, unlike the optimal rule, can more easily lead the economy on a monotonic adjustment path. Indeed for both parameters monotonic convergence is guaranteed. Yet, with higher values of the inflation-expectations parameter $\xi$ and of the rigidity parameter $\kappa$ the domain of coefficient $\gamma_\pi$ consistent with monotonic stability is substantially reduced.

A second observation concerns the effects of inflation expectations and price flexibility. Indeed, the boundedness principle is more stringent, the larger are parameter $\xi$ and $\kappa$, i.e. the closer is the economy to the ideal type of competitive market with rational expectations. These effects are related to the deviation-amplifying role of the expectations.\(^{14}\)

The dynamics of the model depends also on the values of the deep parameters. As I have previously pointed out, a key role is played by the parameter which measures the responsiveness of the capital stock to the rate of interest, namely $\nu$. If the reactivity is low, the output gap and inflation gap will have the same sign. Conversely, if the elasticity is high, a conflict of objectives for the central bank will emerge. In both cases it becomes dangerous to rely on output gap and inflation gap to implement a consistent monetary policy.

\(^{14}\)This is exactly the opposite of what we observed in the case of optimal rule (see Table 3), where the upper bound of the inflation coefficient $\gamma_\pi$ increased with an increase of both $\xi$ and $\kappa$. 

---

<table>
<thead>
<tr>
<th>Weight of short-term rational expectations</th>
<th>Type of convergence</th>
<th>Sticky-price parametrization $\kappa=0.1$</th>
<th>Intermediate-case parametrization $\kappa=0.4$</th>
<th>Flex-price parametrization $\kappa=0.7$</th>
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</thead>
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<td>Monotonic</td>
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<td>$\gamma&lt;3.6$</td>
<td>$\gamma&lt;1.7$</td>
</tr>
<tr>
<td></td>
<td>Oscillatory</td>
<td>never</td>
<td>$\gamma&lt;7.7$</td>
<td>$\gamma&lt;3.7$</td>
</tr>
<tr>
<td>$\xi=0.5$</td>
<td>Monotonic</td>
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<td>$\gamma&lt;1.8$</td>
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<td>Oscillatory</td>
<td>never</td>
<td>$\gamma&lt;3.9$</td>
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<td>$\gamma&lt;0.4$</td>
<td>$\gamma&lt;0.1$</td>
</tr>
<tr>
<td></td>
<td>Oscillatory</td>
<td>never</td>
<td>$\gamma&lt;0.9$</td>
<td>$\gamma&lt;0.2$</td>
</tr>
</tbody>
</table>

Table 4 - Adaptive rule. Values of oscillatory and monotonic-stability upper bounds for $\gamma_\pi$ assuming $\gamma_i = 0.1$ and $\gamma_y = 0$. 

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On one side, if the output gap and the inflation gap were positively correlated, a good rule need not (and should not) react to both gaps: stabilizing output also stabilizes inflation and vice-versa. On the other side, if we had an output/inflation trade-off, trying to simultaneously correct both the gaps can prolong the adjustment dynamic towards the equilibrium, or even steer the system towards different divergent trajectories. Therefore, we have to choose one of the two gaps on which to base the rule.

It is convenient to see all these properties numerically. Let me consider the usual stylized parametrizations base on \( \kappa \) and \( \xi \) and our benchmark flex-price economy (\( \kappa = 0.7, \xi = 0.9 \)). Now, for sake of comparison with the simulations with the optimal Taylor rule, consider the case of a pure inflation-targeting regime as those implied by Figure 3. Recall that this configuration with the optimal rule with lagged information was always explosive. The economy’s dynamic path with our adaptive rule is portrayed in Figure 4-5: it is convergent and oscillatory for \( \gamma_\pi = 0.2 \) and \( \gamma_y = 0 \), and convergent and monotonic for \( \gamma_\pi = 0.1 \) and \( \gamma_y = 0 \). Figure 6 portrays the same economy and policy regime in the intermediate-case (\( \kappa = 0.4, \xi = 0.5 \)). Unlike what happened in the case of optimal rule, where we have oscillatory convergence (Figure 2), now the economy’s dynamic path is monotonically convergent.

At this point we may argue that adaptive interest-rate rules present some desirable properties in the context of investment-saving imbalances. This conclusion adds to similar positions in the recent literature referred to traditional DSGE models (Orphanides and Williams, 2002b). In the first place, adaptive rules economize on hard information about natural rates the lack of which may jeopardize the stabilizing role of monetary policy. At the same time, simple adaptive reaction functions to changes in observable data on inflation and output support the existence of a zero-gap steady state for the saving-investment processes. In particular, the previous simulation (see Table 4) suggests that with sufficiently low interest-rate rule coefficients, the economy may be kept on a monotonically-stable path. This convergent dynamic process is consistent with the alleged preference of policymakers for smooth stabilization, while allowing for greater efficiency in terms of output and inflation gaps. Convergence and stability under the “boundedness principle” are highly sensitive to the structural parameters, first and foremost the degree of price stickiness and the inflation expectations. The ensuing boundary conditions on the coefficients of the interest-rate rule are more binding, the more the economy is characterized by competitive markets and short-run rational expectations.

Economizing on information may be a necessity not only with reference to the natural rates but also to other structural parameters governing the adjustment process. This may in particular be the case with the inflation expectations, which may be hard to pin down especially if they change endogenously with the adjustment process (Mazzocchi, 2012). The region
between the ONS case and the NCM case is large. This may call for sensibly conservative parametrization to hedge against lack of precise knowledge of the structural parameters of the economy.

Finally, there is at least one case worth considering in which even a well-behaving adaptive rule may not work properly. It concerns the key signaling role of excess inflation. It is clear that the entire adjustment process hinges on the fact that inflation - typically the consumer price index, CPI - does respond to output gaps - i.e., excess demand - to an extent that should be deemed significant by the central bank. But if we take into account also the capital stock adjustment we should admit that the change in the structure of production determined by an interest-rate gap may generate a little variation in prices. In fact, as long as firms are allowed to invest in excess of saving, the production capacity in the economy increases, and a stronger activity level may be sustained with less inflationary pressure. This fact, together with the combination of preference for smooth monetary policy - namely, small $\gamma_\pi$ - and sticky-prices/sticky-expectations - i.e., small $\kappa$ and small $\xi$ - may determine and extremely slow, if not flat, adjustment path of the economy toward the steady-state. As an example, look at the simulation in Figure 7 based on the sticky-price parametrization ($\kappa = 0.1$, $\xi = 0.5$) and with representative interest-rate rule coefficients given by the average values of the empirical estimates ($\gamma_i = 0.5$, $\gamma_\pi = 1.5$, $\gamma_y = 0.5$). It is clear that the extraordinarily good performance in terms of price stability is due both to the structural low sensitivity of inflation and the capital stock adjustment. The other side of the coin is that output gaps, which indicate the ongoing investment-saving process, persist for much longer and reach a much larger cumulated value. In this context monetary policy may let financial imbalances mount up which remain disguised in an economic environment that seems to be optimal, i.e., low inflation and sustained economic activity. This scenario was exactly the adjustment path of the economy indicated by the model when parameter $\kappa$ is low as can be seen from estimates in Table 1. This seemingly golden age may mislead the monetary authority and may be mistaken as a sustainable intertemporal equilibrium. This result may also lead to the criticism that inflation targeting per se may be misleading in the event of investment-saving imbalances, so that broader measures or alternative indicators for monetary policy are advocated.

As shown by Table 5, except in cases where agents have forward-looking expectations (namely $\xi = 0.9$), an immediate alternative suggested by the model itself is that output gaps - instead of inflation gaps - convey stronger

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15The flattening of the Phillips curve - i.e., a fall in our parameter $\kappa$ - has been largely documented (Mishkin, 2008).

16Recent research (Bean, 2003) has argued that “flexible”, forward-looking, inflation targets are enough to control for development of financial imbalances, but it is not clear how longer-run forecasts of the future developments of economic activity may overcome the “missing inflation” problem if this is due to a low $\kappa$ parameter.
signals that a disequilibrium process is under way. Adding more weight to output gaps than to inflation gaps may lead to faster correction of the problem (see Figure 8):

Yet this simplicistic solution cannot be taken at face value. It may be difficult for a central bank to explain that a tight monetary policy is necessary when economic activity is high and inflation is low. Thus, the search for broader set of direct indicators of financial imbalances seems necessary.

4 Conclusions

Let me briefly summarize the main finding of this paper. In the model presented business cycles are driven by investment-saving imbalances which generate an intertemporal spillover effect that transmits the effects of present interest-rate gaps to present and future output and inflation. Nominal price (or wage) stickiness is not the exclusive problem, price (or wage) flexibility is not the exclusive solution. The focus is mainly on the fact that the natural rate of interest is volatile and that it is not easily transmitted to the capital market. Since the natural rate of interest consists of the marginal efficiency of capital and core inflation, these properties should apply to both components or at least one. In developed countries with relatively stable and predictable inflation, the candidate to trouble-making remains the marginal efficiency of capital, and in this respect the inflexibility of the nominal market rate of interest determined by the asymmetric information, the heterogeneity of firms, and other New Keynesian explanations may have a role to play (Mazzocchi, 2013b, Messori, 1996).

As long as the system has a nominal anchor - for example, a given core inflation rate in which agents have reason to believe - and the market inter-
The interest rate is driven to close the gaps with the natural rate of interest with a monetary feedback rule, the system will converge to the steady-state equilibrium. Nonetheless, this class of cycles remains relevant to the extent that interest rate gaps are likely, substantial and persistent. Even when the long-run dynamic is converging toward the equilibrium, frequency, amplitude and persistence of these cycles may make them problematic enough in the short and medium run.

Looking at monetary policy, the main conclusion to be drawn so far is that the critical elements that eventually determine whether a rule is good or bad are not the parameters but the crucial piece of information about the natural rate of interest and the natural rate of output: none of the traditional rules produces good results if the central bank is misinformed about these variables. If informational problems with a volatile marginal efficiency of capital are the crux, then interest-rate mechanisms relying upon timely and precise knowledge of the natural rate of interest are inapplicable (Orphanides and Williams, 2002b; 2002a). Simulations have shown that these mechanisms are destabilizing if they embody the wrong natural rate of interest. Thus, unless we can be highly confident that central banks are better (perfectly) informed than the market about the natural rates, “adaptive” rules, using step-by-step adjustment of the interest rate with respect to the different observable conditions in the economy is preferable in that it produces adjustment paths which are generally slower, but safer.

Finally we saw that saving-investment imbalances could build up also in a low inflation environment. The main reason may be that as long as firms over-invest, the stock of physical capital and productive capacity increase. As a result output grows, excess demand is offset over time and inflation is damped. This type of prediction is similar to the one made by Casares and McCallum (2000), where the output gap is very sensitive to the interest rate, whereas the opposite can be said of inflation. As Leijonhufvud (2007) recently argued, inflation targeting not only will not protect by itself against financial instability, but it might mislead into pursuing a policy that is actively damaging to financial stability. Recent episodes in the US seem to confirm this view. An adaptive interest-rate rule specified solely in terms of output is safer and performs better than the other rules in most of the cases. When agents form forward-looking expectations, the central bank may face a trade-off between small gaps and small paths in the adjustment process. The preference for smooth paths - i.e. monotonic convergence - entails a bounded reaction to output gaps and longer persistence of imbalances.

\[17\] The model employed in this paper is open to an alternative interpretation of the robustness of its stabilizing mechanisms: this mechanisms drive the system back to any value of the natural rates in which agents - and the central bank - consistently believe, that is to say, these beliefs are self-fulfilling.
References


Figure 1  Optimal rule, pure inflation targeting. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.1$ and $\xi = 0$

Figure 2  Optimal rule, pure inflation targeting. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.4$ and $\xi = 0.5$
Figure 3 Optimal rule, pure inflation targeting. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.7$ and $\xi = 0.9$.

Figure 4 Adaptive rule, pure inflation targeting. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.7$ and $\xi = 0.9$ - Oscillatory convergence.
Figure 5 Adaptive rule, pure inflation targeting. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.7$ and $\xi = 0.9$ - Monotonic convergence

Figure 6 Adaptive rule, pure inflation targeting. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.4$ and $\xi = 0.5$
Figure 7 Adaptive rule. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.1$ and $\xi = 0.5$ and empirical interest-rate coefficients $\gamma_i = 0.5$, $\gamma_\pi = 1.5$ and $\gamma_y = 0.5$.

Figure 8 Adaptive rule. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.1$ and $\xi = 0.5$ and empirical interest-rate coefficients $\gamma_i = 0.5$, $\gamma_\pi = 0$ and $\gamma_y = 0.5$. 

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