

Essays on
THE MACROECONOMICS
OF INVESTMENT-SAVING IMBALANCES

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Introduction

Over the past decades much of the world has entered a phase of low and stable inflation. No doubt several factors have contributed to this development. As to whether low inflation guarantees continuing good economic performance, economic historians would remind us both of the global depressions that began in 1874 and 1929 and of the severe troubles faced by the Nordic countries and Japan in the early 1990s and by other countries in Asia after 1997. In none of these cases was the turmoil preceded by any significant degree of inflation. However, in each case the rate of credit expansion had been very rapid. On the other hand, many pre-war business cycle theorists noted that, in economies benefiting from increases in productivity, prices should naturally be falling. Monetary policy may thus unwittingly accommodate the build up of financial imbalances and associated distortions in the real economy, notably excessive capital accumulation.

The problem is that the current consensus in macroeconomics does seem inadequate to deal with all these elements. As Lucas (2004) correctly argued “[...] *the new theories embedded in general equilibrium dynamics [...] don't let us think about the U.S. experience in the 1930s or about financial crises and their consequences*”. Despite this and others early warnings from inside, these models were being increasingly used by central banks and were highly fashionable. Only in the last years, with most of central banks failing to see the crisis coming, the models are being questioned. Most of the critics concern the assumptions of modern macroeconomics, the inadequacies of these theories for dealing with the financial crisis and the consequent spillover effects for the whole economy.

Paradoxically, the models and the theories that are so criticized today were born in response to the crisis of what we may consider the previous consensus. As we show in Chapter 1, the development of the New Neoclassical Synthesis (NNS) has its origins in the 1970s when the existing conventional quantitative macroeconomic models,

rooted in Keynesian economic theory, were heavily criticized on both theoretical and empirical grounds (Sims, 1980). Existing mainstream macroeconomic models showed a poor forecast performance, missing the economic reality of stagflation. As a result, the general applicability of these models for forecasting and policy analysis was questioned. In his famous critique of econometric policy evaluation, Lucas (1976) emphasized the lack of structural invariance of those macroeconomic models making them unfit to predict the effects of alternative policies.

A response to this critique emerged in the form of the first generation of dynamic stochastic general equilibrium (DSGE) models. The development of these models was a merit of the real business cycle (RBC) approach initiated by the seminal work of Kydland and Prescott (1982) and Long and Plosser (1983). Based on the frictionless neoclassical growth model, the RBC approach aimed to explain economic fluctuations as an optimal response of rational agents to real disturbances, particularly technology shocks. From this paradigm, a distinct school of thought evolved becoming known as New Keynesian economics. Originally derived as an extension to the standard real business cycle framework, which features monetary neutrality due to the presence of flexible prices and wages, New Keynesian economics evolved into a progressive research program - namely, the NNS - accounting for the real effects of monetary policy. The strategy was to minimize the frictions that are required to reproduce both persistent real effects of nominal shocks and interaction of interest and prices in a rigorous framework with intertemporal optimization, forward-looking behavior and continuously clearing markets. The claim is that the NNS model is capable of rigorously reproducing observable phenomena and is able to provide a microeconomically well-founded basis for the design of optimal policy rules, since it is amenable to welfare analysis. Nevertheless these results come at the price of many ad-hocery and other shortcomings which are indispensable for intertemporal equilibrium modeling. The main theoretical weakness of the NNS is that it does not consider *intertemporal coordination failure* and therefore the possibility of saving-investment imbalances. Indeed the NNS framework is set in continuous intertemporal equilibrium and cannot deal with imbalances of planned saving and investment, nor can it deal with financial intermediation and its effects on budget constraints in the long run. Deviations from the optimal growth path of the economy are essentially explained in terms of sticky-prices, sticky-wages or other imperfections in the goods or labour markets.

The lack of these elements led me to develop a different theoretical framework. In Chapter 2 I present a dynamic model with endogenous capital stock whereby it is possi-

ble to assess - and hopefully clarify - some basic issues concerning the macroeconomics of investment-saving imbalances. By way of contrast with the NNS triangle (Mazzocchi et al., 2009; Tamborini et al., 2013) of intertemporal optimization, imperfect competition and sticky prices, the suggested model reject three things: perfect information, efficient financial market hypothesis and dynamic stability by assumption. Three are the main finding of the model. First, investment-saving imbalances trigger disequilibrium business cycles with endogenous *real* as well as *nominal* effects. Second, these cycles display endogenously the autocorrelated dynamic structure that is typically observed in the data. Therefore the dynamic properties of the system with respect to the NNS standard model are considerably modified. Third, these processes persist as long as the misalignment of the market interest rate with respect the intertemporal general equilibrium rate persists. Wage and price stickiness is not the only problem, wage/price flexibility is not the only solution.

This last result can have very important implications in terms of monetary policy. This is what I analyze in **Chapter 3**. Unlike what usually stated in the literature, the critical elements that eventually determine whether a rule is good or bad are not the policy parameters associated to the inflation-gap or the output-gap, 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. Simulations will show that monetary policy rules are destabilizing if they embody the wrong natural rate of interest. Thus, unless we can be highly confident that central banks are perfectly informed than the market about the natural rates, *adaptive* rule, 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.

Moreover, the model is also able to show that saving-investment imbalances could build up also in a low inflation environment. The main reason is that as long as firms over-invest, the stock of physical capital and thus the productive capacity increases. As a result output grows, excess demand is offset over time and inflation is damped. In this case monetary authorities may not be able to identify the financial imbalances sufficiently early and with the required degree of comfort to take remedial action. The traditional inflation targeting strategy (Svensson, 2010) pursued by many central banks around the world not only will not protect by itself against financial instability, but it might mislead into pursuing a policy that could actively damaging financial stability. These element suggests that output fluctuations are the more reliable signals for

monetary policy than inflation.

Recent episodes in the U.S. seem to confirm this view. **Chapter 4** is entirely devoted to the debate on the real or alleged faults of the Federal Reserve Bank of U.S. before the financial crisis of 2007. Some economists argue that in the period 2002-2005 the U.S. central bank has taken its target interest rate below the level implied by monetary principles that had been followed for the previous 20 years. One can characterize this decision as a deviation from a policy rule such as a Taylor rule. This behavior determined the end of the Great Moderation and gave birth to the Great Recession. In this chapter I challenge this view. I show how the deviations from the Taylor-rule's hypothetical interest rate can be explained by the ambiguity on inflation indicators to use. I also explain how the *Great Deviation* (Taylor, 2010) was instead caused by an error in the estimate of one of the fundamental components of the Taylor rule, i.e. the natural rate of interest. Too expansionary monetary policy of the Fed was therefore not due to discretionary choices, but to a *structural* problem of the Taylor rule. Finally, I show how an adaptive rule based only on observable variables with an higher weight to the output dynamics would have avoided the huge gap between short-term rates and natural rates.

Chapter 1

Scope and Flaws of the New Neoclassical Synthesis

1.1 Introduction

Over the last 30 years the global financial markets have become increasingly volatile, with bubbles and crises alternating in ever larger waves at shorter intervals. It was perhaps all the more surprising that macroeconomics, during the same period, essentially began to redevelop around the core of the *efficient market hypothesis* of finance theory. Rational expectations, efficient processing of informations in the markets, perfect coordination through price mechanisms were the main ingredient of the macroeconomic debate between the 1980s and 1990s. Surely there were still, for a while, a lot of controversies between the so called Real Business Cycles theory (RBC), the New Keynesian Economics (NKE) and the diverging approaches that look at the consequences of information asymmetries and other market imperfections that may cause financial crises, mass unemployment and other macroeconomic pathologies.

In the Nineties the combined assault of the time inconsistency problem and the RBC literatures (Kydlund and Prescott, 1977; 1982) eventually led to the formation of consensus models called *New Neoclassical Synthesis* (Goodfriend and King, 1998; Blanchard, 2000). Like the Old Neoclassical Synthesis of Hicks, Samuelson and Patinkin, the New Neoclassical Synthesis (NNS) tries to link micro- and macroeconomics, using a general equilibrium framework to model some typically Keynesian features. The main idea of this literature is to furnish a common vision of neoclassical and Keynesian theories entrusting to them separate roles in the construction of the model: the RBC part of the model explains the evolution of the potential output embodying *Dynamic Stochastic*

General Equilibrium models (DSGE), while the transitory deviations from this trend are explained using the slow adjustment of prices and wages which were developed in the 1980's by the NKE. Like RBC models, the NNS assigns a very important role to real shocks in the explanation of short run fluctuations; numerous recent studies have shown how monetary policy is able to explain only a part of economic fluctuations, and therefore real shocks play an essential role in the study of business cycle¹. Differently from the RBC models, however, the NNS does not consider these fluctuations efficient and desirable, and does not think that monetary policy is totally ineffective. In fact, because of the delays in the adjustment of prices and wages, the consequences of real shocks are undesirable. An active economics policy can therefore intervene to reduce these distortions.

The NNS became the consensus view not only because of the elegant theoretical formulation, but also because it seemed to be successful. The reduction in the volatility of business cycle fluctuations starting in the mid-1980s, the low inflation and the predictable policy were long seen as the new theoretical framework was correct (Clarida, 2010). However the so-called *Great Moderation* (Stock and Watson, 2002; Bernanke, 2004) is now also interpreted as missing inflation that followed from a combination of global financialization and balance of payment imbalances (Borio and Lowe, 2002). Moreover the conventional wisdom on the links between monetary and financial stability² has been seriously questioned. While the empirical evidence is broadly consistent with the idea that monetary instability can cause financial instability, the interpretation of this evidence - and the policy conclusions that follow - could be criticized under different point of view. In particular, the evidence does not mean that either unexpected changes in the inflation rate are by themselves the major source of instability or that financial imbalances will not develop in a low and stable inflation environment. The coexistence of an unsustainable boom in credit and asset markets on one side, and low and declining inflation on the other can be explained by a large number of factors. The main reason³ is the positive association between favorable supply-side

¹This has also an important theoretical implication: the impact of the Neoclassical Counterrevolution of the 1970s has not established a new vision of the macroeconomic phenomenons (which was the explicit aim of the Real Business Cycle authors), but it has instead forced the old mainstream to adopt new and more sophisticated methodological techniques.

²This link is nicely summarized by Bordo et al. (2000) who write that "*a monetary regime that produces aggregate price stability will, as a by-product, tend to promote stability of the financial system*".

³Other relevant factors could be the successful implementation of the stabilization programs after the 1970s, which anchors price expectations and lead to a significant reduction in inflation. These situation create a general optimism about the future economic perspectives, which can underpin a

developments (which push down the prices) and asset price booms (easier access to external finance and optimistic assessment of risk)⁴. 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 productivity⁵. On this line we can mention the contribution of Mandelbrot (2005) who argued that it was the abuse of the efficient market hypothesis - and the underlying assumptions of white noise and Gaussian normal distribution - that prevented economists and analysts to contemplate both increasingly risky behaviour on behalf of financial intermediaries and their clients. This fault - together with a benign neglect of asset price inflation and systemic risks on behalf of the central banks and supervisory authorities (Bernanke and Gertler, 1999; 2001) - has undoubtedly contributed to destabilize the economic system (Leijonhufvud, 2007).

It is not necessary to go as far as fractal geometry or other more complex theories of turbulences to explain the basic macroeconomic problem underlying the great credit crisis and many of the developments prior to it: *investment-saving imbalances* and their consequences for the formation of budget constraints and expectations. The coordination of saving and investment decisions was analyzed by earlier macroeconomics, especially in the works of Wicksell (1898a), Keynes (1930, 1936, 1937b), and their respective followers (Lindahl, 1930; Lundberg, 1937), but in the last forty years it was drifted so far out of focus as to be virtually forgotten. The intertemporal coordination failure problem is especially important because, without it, we are left with theories of unemployment that look only at the imperfections in the labour/goods markets and do not seem able to explain the real phenomena.

At the beginning of the last decade Michael Woodford gave the impression to brought back to center stage pre-Keynesian macroeconomics. In his authoritative contribution *Interest and Prices* (2003) he furnished an excellent representation of the

consumption and lending boom, often financed by inflow of foreign capital. 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.

⁴In 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

⁵Yet, a self-reinforcing boom can emerge, with increases in asset prices supporting 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.

dynamic interaction between interest rates, price level and output⁶. The book self-consciously borrows its title from Knut Wicksell's (1898a) masterpiece on monetary economics and indeed the main aspect of Woodford's contribution is the rediscovery of the Wicksellian nominal interest rate, *vis-à-vis* the "natural" interest rate prevailing at full-employment general equilibrium, as the pivot of rule-based monetary policy. Unfortunately in the book most of the pre-Keynesian features are notably absent. In particular, Woodford does not consider the presence of frictions in the capital market which generates the first pillar of the Wicksells view, i.e. the bank intermediation among savers and investors. Moreover there is no room for information problems and the intertemporal disequilibrium which could produce the well-known dynamics of money creation, of prices and of nominal income, i.e. the so-called *cumulative process* (Boianovsky and Trautwein, 2006b). These weaknesses not only prevent the discussion of the effects and the relations between financial market and the real economy, which were the core of old macroeconomics, but it seems to have led economic theory far away from the understanding of the behaviour of global economy in the last decades. Coordination failures in the market system that have their origin in the capital markets and cannot independently be corrected in the goods or in the labour markets: if there is a discrepancy between saving and investment at the full employment rate of real income, the flexible adjustment of money wages will not restore the economy at its potential level but rather can make things worse.

The chapter is organized as follow. Section [1.2] offers a historical reconstruction and clarifies some basic theoretical issues underlying the NNS. Section [1.3] explores the alleged "Wicksell connection" of the NNS put forward by Woodford. Section [1.4] presents a model with endogenous determination of the capital stock whereby it is possible to assess some basic issues concerning the current consensus in macroeconomics. Section [1.5] shows the main weaknesses of NNS framework with particular emphasis on coordination and information problems. Section [1.6] concludes.

1.2 From the Old to the New Neoclassical Synthesis

In the last twenty years we have seen the development of a new macroeconomic framework usually defined as an IS-LM model of second generation, designed to replace the

⁶Many economists have noted the contrast between the title of Patinkin's treatise (1965), *Money, Interest and Prices*, and Woodford's *Interest and Prices* as making it very clear the diminished role of the quantity of money in modern macroeconomic theory.

traditional one in the academic research and in the teaching activities. The Hicksian's interpretation of Keynes' work (Hicks, 1937) was the origin of the first consensus view that came to be dubbed "*Neoclassical Synthesis*" by Paul Samuelson (1951, p. 336). Its basic tenets were that market systems would be hypothetically self-stabilizing around full-employment equilibrium, but that, in reality, they would frequently tend to settle for inefficient states of underemployment equilibria. Such constellations could occur in cases of extreme liquidity preference in financial markets (liquidity trap), strong pessimism of business firms in the goods markets (investment trap), or nominal wage stickiness in the labour market (nominal rigidities).

Even though IS-LM modeling was confined to comparative-static analysis of equilibria in goods and asset markets, underemployment was conceived as a disequilibrium phenomenon. A part of the labour force would be involuntarily unemployed as market forces fail to push the economy back to full employment equilibrium starting from an intersection of IS - goods market equilibrium - and LM - asset market equilibrium - at which the labour market is out of equilibrium. It was argued that the state ought to play the role of a benevolent social engineer who minimizes the negative welfare effects of macroeconomic malfunctionings by way of fiscal and/or monetary measures to stabilize aggregate demand.

This first consensus view essentially combined at least some neoclassical modes of thinking with Keynesian prescriptions for economic policies to reduce or even to dissolve underemployment in the short run. Full-employment IS-LM was taken to correspond with the long-run perspective of the standard Solow model of steady-state growth (Solow, 1956), even though the two frameworks were not well connected. Since liquidity and investment traps came to be increasingly considered as empirically irrelevant or episodes of market psychology confined at best to the very short run, the Keynesian explanation of underemployment slowly boiled down to wage rigidities. In this respect, the consensus view embodied in the old synthesis did no longer differ much from the approaches of pre-Keynesian neoclassics, such as Cassel (1918) or Pigou (1933). Since nominal rigidities and pessimistic profit expectations were seen as a short-run phenomena that would be eliminated sooner or later by market forces, it was considered plausible that thinking about economic growth could be based on entirely different analytical frameworks, where differences between the neoclassical concept of marginal productivity and the Keynesian concept of the marginal efficiency of capital would not matter.

Up to the 1950s this model was very successfully. This was possible for some im-

portant circumstances: first, the presence of a certain monetary stability and of rather peaceful industrial relationships that justified - at least in the short run - the basic hypothesis of fixed prices and wages. Second, the slow shifts of the aggregated supply curve observed in the empirical data allowed economists to consider it as fixed, at least in the medium run. Finally, the substantial stability of the two curves allowed economists to use the IS-LM model for designing possible macroeconomic policies. Starting from the 1960s, and particularly toward the end of the decade, it was however clear that the IS-LM model could not represent a general vision of the economy, and that the supply side could not be neglected, even in the short period. The need to develop an *ad hoc* price-wage equation was solved with the introduction of the Phillips curve. Nevertheless, the lack of coherent expectations⁷ and of structural relationships derived from a maximization process of rational agents constituted meaningful objections that conducted to the collapse of the old Neoclassical Synthesis.

The pendulum of high-brow opinion swung back to the view that market systems are inherently efficient and stable. The Neoclassical Synthesis came under heavy fire by the Monetarist and New Classical “counter-revolutions”. The emphasis put on the need to incorporate the rational expectations in the model has conducted to a first reformulation of the IS-LM model: using the Lucas’ AS curve (Lucas, 1972) in place of the traditional Phillips curve, it showed the irrelevance of macroeconomic policies and the impossibility of inefficient equilibrium according to the conclusions obtained by Sargent and Wallace (1975). Starting from the 1980s the DSGE methodology - in particular its more popular version, the RBC model - has become the major paradigm in macroeconomics. Its essential features are the assumptions of intertemporal optimizing behavior of an economic representative agent⁸, competitive markets and price-mediated market clearing through flexible wages and prices. It therefore assumes that all markets - including product, capital and labour markets - are cleared in all periods, regardless of whether the model refers to the short run or the long run. The continuous market clearing hypothesis requires that prices are set at an equilibrium level, which can be proved under certain assumption. But little has been said about how the general equilibrium can be achieved. In an economy in which both firms and households are price

⁷The importance of the expectations was underlined already from Keynes but in his works there were privileged the exogeneous one, i.e. not connected with the evolution of the state and control variables.

⁸While Ramsey (1928) constructed his famous model to provide the basis for the normative analysis of a central planner’s problem of maximizing society’s consumption over time, writers in the RBC tradition have reinterpreted it as a positive description of a decentralized economy.

takers, an auctioneer who adjusts the price toward the general equilibrium is implicitly presumed to exist. Therefore, how an equilibrium is brought about is essentially a Walrasian *tâtonnement* process. Since output fluctuations are basically considered to be optimal response, the RBC theorists reject the old Keynesian view that the state ought to stabilize aggregate demand. On the contrary, they argued that problems of dynamic inconsistency would make discretionary action to stabilize output or price level ineffective, if not inefficient (Barro and Gordon, 1983).

Working with such framework of competitive general equilibrium is elegant and perhaps convenient. Nevertheless, this model was totally unsatisfactory for different points of view. It neglects many restrictions on the behavior of agents: the trading process, the market-clearing process, the implementation of new technology, the market structure and many others. Moreover the RBC model fails to replicate essential product, labour and capital market characteristics. All these theoretical contributions were criticized especially regarding the impulse mechanism. In the standard DSGE model, technology shocks are the driving force of the business cycles and are assumed to be measured by the Solow residual. However, there are several reasons to distrust it as a measure of technology changes. First, Solow residual is computed on the basis of observed output, capital and employment and it is presumed that all factors are fully utilized. Second, Mankiw (1989) and Summers (1986) have argued that such a measure often leads to excessive volatility in productivity and even to the possibility of technological regress, both of which seems to be empirically implausible (Calomiris and Hanes, 1995). Third, it has been shown that the Solow residual can be expressed by some exogenous variables that are unlikely to be related to the factor productivity⁹. Fourth, the Solow residual can be contaminated if the cyclical variations in factor utilization are significant. Another main weakness of the RBC models - that is rather consistent with the transmission mechanism - is that technology shocks are strongly pro-cyclical: these models predicts a significantly high positive correlation between technology and employment (Stadler, 1994), whereas empirical research demonstrates a negative or almost zero correlation (Galí, 1999; Francis and Ramey, 2005, 2003).

⁹Jorgenson and Griliches (1967) show that the Solow residual, rather than changes in technology, highlights changes in the use of capital and the labour-hoarding phenomena. Hall (1986, 1990) shows that the distribution between labor and capital occurs according to the exponents of the Cobb-Douglas only in the case of perfect competition environment. Therefore in imperfect competition the Solow residual includes also changes in mark-up over the business cycle. Moreover if we admit increasing returns to scale the Solow residual is almost entirely determined by components other than pure technological shocks. Empirical evidence on this point is provided by Hartley (1994).

The dissatisfaction with the RBC models stimulated research to move towards a post-Walrasian microeconomics in order to derive the commonly observed macroeconomic phenomena from correct microeconomic principles (Stiglitz, 1991). Over the last decades a shift has begun away from a concentration on the Walrasian price-taker models towards a world where firms may be strategic agents. This new approach uses the standard tools of New Classical Macroeconomics (NCM): consumers, workers and firms are rational, agents always maximize and markets clear. But the output of these new models follows Keynesian lines: the aggregate economy has multipliers, economic fluctuations are not Pareto optimal, and finally government interventions can be effective to control business cycles.

Imperfect competition is a key assumption of this approach (Blanchard and Kiyotaki, 1987; Dixit and Stiglitz, 1977): it opens new channels of influence of monetary policy but also creates the possibility that an increase in output may be welfare improving (Cooper, 2004). To ensure that aggregate demand is always sufficient to match aggregate supply - other than simply assuming it - further conditions need to be fulfilled. Thus it must be assumed that households own firms, that they receive firm's profits as part of their income in each period, and that there are no distribution effects of output and inflation gaps that could feed back onto the latter. All these elements are taken care of by the conventional assumption of the representative household. Finally, the assumption that both households and firms have rational expectations of future output and inflation gaps makes the optimal plans self-fulfilling, at least in the absence of shocks. In this setting, output and inflation gaps have no influence on the speed and extent to which information is incurred, processed and used for predictions.

Imperfect competition by itself does not create monetary non-neutrality¹⁰, but its combination with some other distortions can generate potential real effects (Fischer, 1977; Taylor, 1979b; Taylor, 1980; Ball et al., 1988). The existence of nominal rigidities in the goods markets is, in fact, crucial for generating suboptimal equilibria in this new framework. Sluggish price adjustments are introduced in order to make profit-maximizing firms choose between price and output adjustments in response to disturbances that affect marginal costs (Woodford, 2003, ch.3). These menu costs and other

¹⁰Woodford (2003) actually uses the strong assumption of a monopolistically competitive system with *flexible* prices, in which output growth would not substantially differ from that of a perfectly competitive system, to define the so-called natural rate of output. This rate, and hence the fiction of imperfect competition with fully flexible prices, serves as benchmark for assessing the welfare losses that accrue from sticky prices.

rigidity components are exogenously given¹¹.

In the last fifteen years many attempts have been made to introduce all these “Keynesian” features into DSGE model. In those types of models, producers set the price optimally, according to their expected market demand curve. If one follows a Calvo price-setting scheme (Calvo, 1983), there will be a gap between the optimal price and the existing price. However, it is presumed that the market is still cleared, since the producer is assumed to supply the output according to what the market demands at the existing price. Yet, by stressing nominal rigidities in the model, in case of unexpected shock not all markets may be cleared even with dynamically optimizing agents. Therefore sticky prices can explain suboptimal output fluctuations and provide a substantial role for monetary policy to reduce welfare losses. This last element was introduced in the model when Taylor (1993) described the observed behaviour of central banks in terms of a simple feedback mechanism. This gave rise to a large literature about the so-called Taylor rule (Orphanides, 2007) that consists of reaction function by which central banks adjust their key interest rates to take account of deviations of inflation and output from their target values.

1.3 NNS in a Neo-Wicksellian Framework

Along the lines described in the previous section, a new consensus developed in the late 1990s. Blanchard (1997) observed that almost all macroeconomists now work within a framework that combines three ingredients: intertemporal optimization, imperfect competition and nominal rigidities. This combination characterizes what is generally labelled the *New Neoclassical Synthesis* (Goodfriend and King, 1998) or the *NNS triangle* (Mazzocchi et al., 2009). In analogy with the *IS-LM-AS* of the illustrious ancestor, the canonical NNS model can be characterized as *IS-AS-MP*, a three-equations system through which output gaps, inflation gaps and interest rates gaps are jointly determined. An intertemporal IS curve, derived from RBC theory and formulated in DSGE terms, is combined with an aggregated supply function in terms of a Phillips curve with expectations (AS) and a reaction function for monetary policy (MP), usually represented in a Taylor rule form (Boianovsky and Trautwein, 2006b; Trautwein, 2006).

On this framework is based most of the current macroeconomic literature (Clarida et al., 1999; Romer, 2000), and its most authoritative statement is found in Michael

¹¹Another approach to the study of nominal rigidities is that proposed by Akerlof and Yellen (1985b, 1985a), which justify the barriers to the adjustment of prices with the presence of “*quasi rationality*”.

Woodford's *Interest and Prices*, which provides both comprehensive summary and numerous extensions of the NNS. The main objective is to develop a framework for monetary policy analysis that is based on dynamic, optimizing, general equilibrium analysis in a stochastic context, while departing from RBC assumptions by replacing the latter's presumption of full price flexibility with an optimizing form of nominal price stickiness. All the models contained in the book are usable for analysis of alternative policy, with much concern given to the design of an optimal policy rule, with optimality evaluated in terms of the utility of a typical household. Woodford shows that non-policy forces affecting output behaviour can be summarized in terms of a natural rate of interest, i.e. the time varying equilibrium real rate of return that one would obtain if prices were fully flexible. Woodford (2003, ch. 4) describes his models as a "neo-Wicksellian framework" just because the output and inflation dynamics are generated by gaps between the natural rate and the market rate of interest. This is clearly reminiscent of Knut Wicksell's *Interest and Prices* (1898a) and of his proposal to eliminate inflation by adjusting nominal interest rates to changes in the price level (an idea that has much in common with modern policy rules *à la Taylor*). In particular, Woodford motivates his advocacy of rules to fight inflation on the potential non-neutrality of monetary policy: [...] *It is because instability of the general level of prices causes substantial real distortions leading to inefficient variation both in aggregate employment and output and in the sectoral composition of economic activity that price stability is important* (2003, p.5). Woodford's theory of monetary policy is based on the assumption that central banks can control short-term market rates of interest and, hence, affect inflation without taking any recourse to monetary aggregates. He argues that the current practice of monetary policy is determined by the implementation of a "channel system" of lending and deposit rates that keeps overnight interest rates in line with the target fixed by the central bank. Since the achievement of this target does not require any quantity adjustment through open market operations, the monetary base does not play any strategic role in the process of controlling inflation.

Despite the numerous praises for the work of Knut Wicksell, Woodford doubts that the original "*Wicksellian theory can provide a basis for the kind of quantitative analysis in which a modern central bank must engage* (2003, p. 5-6). Bridging the gap between the old-style approach and modern econometrics may have its problems, but Woodford brings in intertemporal general equilibrium theory as the main prerequisite for a proper theory of monetary policy. He argues that old-style Wicksellian theory does not conform to "*modern standards of conceptual rigour*", because it lacks explicit microfoundations.

Even though business cycles and growth are analyzed within a single framework that is based on Walrasian principles, “*this does not mean that the Keynesian goal of structural modeling of short-run aggregate dynamics has been abandoned. Instead, it is now understood how one can construct and analyze dynamic general-equilibrium models that incorporate realistic representations of both short-run and longer-run responses to economic disturbances*” (Woodford, 2009). The pivotal role that Woodford’s book has played - at least until the beginning of the Great Crisis - in academic and political debate about modern monetary policy demonstrates the power of the NNS consensus.

Most of the attention of commentators and analysts focused on the basic version of the model. One of the key assumption underlying the benchmark model is that the aggregated demand just consists of consumption. As Woodford (2003, p. 243) points out, the model “*abstracts from the effects of variations in private spending (including those classified as investment expenditure in the national accounts) upon the economy’s productive capacity*”, therefore the model should be interpreted “*as if all forms of private expenditure were like nondurable consumer purchase*”¹². Woodford (2003, p.352) comments on these modeling choices saying that “*while this has kept the analysis of the effects of interest rates on aggregate demand quite simple, one may doubt the accuracy of the conclusions obtained, given the obvious importance of variation investment spending both in business fluctuations generally and in the transmission mechanism for monetary policy in particular*”. Indeed, this approach eliminates one of the main benefits of the DSGE approach begun by Kydland and Prescott (1982), namely that it is inherently intertemporal in nature and incorporates the supply side of the economy. Moreover, the *intertemporal* coordination problem between future consumption (saving) and future production (investment), which is the key problem to be solved by the interest rate in general equilibrium theory, vanishes. There remains the sole *intratemporal* coordination problem between current aggregate demand and supply at each date that is dealt with by the spot price system. Lastly, as King and Rebelo (2000) argue, “*the process of investment and capital accumulation can be very important for how the economy responds to shock*”.

Despite these critical elements, the preference for models without endogenous capital stock depends on different reasons. As rightly pointed out by Laidler (2009), the lack of investment by the NNS models is a remarkable feature of monetarism which abstracted entirely from it in the explanation of fluctuations in nominal income. Moreover,

¹²The same approach is used by Jeanne (1998), Rotemberg and Woodford (1997) and McCallum and Nelson (1997).

sticky price models with endogenous investment imply unrealistically high volatility in the endogenous variables. In other words, changes in nominal interest rates translate one for one into changes in real rates therefore leading to the excessively high volatility of investment. These theoretical shortcomings have been partially overcome assuming staggered price setting *à la Calvo* combined with firm-specific investment by firms¹³. Woodford (2003, ch.5; 2004; 2005), Sveen and Weinke (2003; 2004) and Casares and McCallum (2000) extend the basic framework including capital investment explicitly in the optimizing analysis. The purpose of this extension is not to offer a fully realistic quantitative model of the monetary transmission mechanism but rather to provide insights regarding several modeling techniques that are used in a number of recent examples of estimated models with optimizing foundations.

1.4 The NNS model

The model I present in this section is a simple DSGE with monopolistic competition and nominal price rigidities (Woodford, 2003, 2004; Casares, 2002). It includes the endogenous determination of the capital stock. It considers three types of agent: household, firms and a central bank. Households hold real money balances, choose labor supply and consumption demand. Firms produce differentiated goods and act under monopolistic competition. They face restrictions on both price adjustment and capital accumulation. Finally the central bank set a target of inflation expectations and fix the nominal interest rate. The whole model is fully developed in Appendix at the end of the chapter. Let me show here the most important building blocks of this framework. I restrict my attention to a log-linear approximation to the equilibrium dynamics around a steady-state with zero inflation. Thus the percentage deviation of a variable with respect to its steady-state is denoted by a hat.

The real sector of the economy is derived analyzing the optimal behavior of the households and of the firms and the respective equilibrium conditions. Unlike the basic model, the result is not a single equation, but a system of four equations (Woodford, 2003; ch. 4). The first relation is the household's labour supply equation:

$$\hat{\omega} = \phi \hat{n}_t + \sigma \hat{c}_t \tag{1.1}$$

¹³There are other model with endogenous capital accumulation which assume a rental market (Yun, 1996; Smets and Wouters, 2003; Schmitt-Grohé and Uribe, 2004). However Sveen and Weinke (2004) show that the rental market assumption is not innocuous in a model with staggered price setting.

where $\hat{\omega} = \hat{w}_t - \hat{p}_t$ is the real wage, \hat{n}_t is the labour supply¹⁴ and σ denotes household's relative risk aversion.

The second equation is obtained by log-linearizing the first order condition of optimal intertemporal consumption \hat{c}_t :

$$\hat{c}_t = E_t \hat{c}_{t+1} - \frac{1}{\sigma} (i_t - E_t \pi_{t+1} - \rho) \quad (1.2)$$

where i_t denotes the nominal interest rate, π_t is the rate of inflation and ρ is the time discount rate or the so-called “natural rate of interest” or “Non-Accelerating Inflation Rate of Interest” (NAIRI).

The law of motion of the aggregate capital stock is the following:

$$\hat{k}_{t+1} = \frac{1}{1 + \beta} \hat{k}_t + \frac{\beta}{1 + \beta} E_t \hat{k}_{t+2} + \frac{1 - \beta(1 - \delta)}{\epsilon_\psi(1 + \beta)} E_t \hat{\chi}_{t+1} - \frac{1}{\epsilon_\psi(1 + \beta)} (i_t - E_t \pi_{t+1} - \rho) \quad (1.3)$$

where χ_t denotes the average real marginal savings in labour costs, β is the rate of time preferences and ϵ_ψ are the adjustment costs of capital.

Finally, the level of aggregate spending is given by the following relation:

$$\hat{y}_t = \zeta \hat{c}_t + (1 - \zeta) \frac{1}{\delta} [\hat{k}_{t+1} - (1 - \delta) \hat{k}_t] \quad (1.4)$$

where ζ denotes the steady-state consumption to output ratio while the steady-state capital to output ratio is thus given by $(1 - \zeta) \frac{1}{\delta}$. Moreover δ represents the rate of depreciation of the capital stock.

The system of the previous equations (1.1)(1.2)(1.3) and (1.4) then comprises the IS block of the model which suffices to determine the paths of the variables \hat{y}_t , \hat{c}_t , \hat{k}_{t+1} , $\hat{\omega}_t$ given the initial capital stock \hat{k}_t and the evolution of the short term interest rate $\hat{i}_t - E_t \pi_{t+1}$.

The second part of the model is composed by an AS-block of two equations which investigate the implication of the endogenous capital stock for the price setting decisions of firms. We have to consider that a) the capital stock affects the marginal costs of firms (and therefore the output) and b) how the capital stock will evolve over the time that its price remain fixed. Indeed we assume that firms set prices *à la Calvo*, i.e. in each period only for a randomly selected fraction $1 - \theta$ of enterprises (where $0 < 1 - \theta < 1$) it is possible adjust the price in a period, while the remaining θ firms post their last

¹⁴More precisely n_t is the logarithm of the number of hours worked in each period.

period's price. With probability θ^k a price that was chosen at time t will still be posted at time $t + k$. When setting a new price $P_t^*(i)$ in period t firm i maximizes the current value of its dividend stream over the expected lifetime of the chosen price.

The first problem is solved with a simple manipulation of the marginal costs expression. The second problem takes into account the fact the the price setting decision - in addition to the usual inflation and average marginal cost terms - depends also on the current and expected capital gaps over the random lifetime of the chosen price. Woodford (2004) shows that the associated inflation takes the following form:

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa \hat{s}_t \quad (1.5)$$

where κ is a parameter computed numerically and \hat{s}_t is the real marginal cost.

Finally, the following aggregate production function holds up to a first-order approximation:

$$\hat{y}_t = \alpha \hat{k}_t + (1 - \alpha) \hat{n}_t \quad (1.6)$$

where α is the capital share. Therefore the AS block is composed by equations (1.5) and (1.6) and it provides the characterization of the inflation dynamic $\hat{\pi}_t$ and the labour hours \hat{n}_t , given the evolution of \hat{y}_t , \hat{k}_t and ω_t from the IS block. It takes into account the effect of changes in the capital stock on the real marginal costs and hence on the short-run trade-off between inflation and output.

The monetary policy block is composed by a single feedback equation in a Taylor fashion. It gives us the evolution of $\hat{i}_t = i_t - i^{SS}$, given $\hat{y}_t = y_t - y^{SS}$ and $\hat{\pi}_t = \pi_t - \pi^*$ from the IS and AS block, respectively.

$$i_t = i^{SS} + \gamma_\pi (\pi_t - \pi^*) + \gamma_y (y_t - y^{SS}) \quad (1.7)$$

where the two weight factors γ_π and γ_y are policy coefficients that describe the relative intensity of the interest-rate reactions to deviations of actual inflation and the output gap from their respective target values. The target value for the output gap is defined as the steady-state value of the output gap consistent with the inflation target. This closes the model in two ways. First, it makes the Taylor rule internally consistent, as the definition of y^{SS} ensures that i_t equals i^{SS} whenever the inflation target π^* is achieved. Second, the reaction function for monetary policy permits the determination of the endogenous variables \hat{i}_t , $\hat{\pi}_t$ and \hat{y}_t in the previous equations. Woodford argues that the Taylor rule is optimal if the inflation target is set near zero inflation. In this case, the

welfare losses that arise from price stickiness and the fluctuations and persistence of output gaps will be minimized.

The model thus is composed by seven equations - namely (1.1)(1.2)(1.3)(1.4) (1.5)(1.6) (1.7) - with seven unknowns - i.e. \hat{u}_t , \hat{y}_t , \hat{n}_t , \hat{c}_t , $\hat{\omega}_t$, \hat{k}_{t+1} and $\hat{\pi}_t$, with one predetermined variable \hat{k}_t .

1.5 Strengths and weaknesses of the NNS framework

1.5.1 Monetary foundation, nominal rigidities and problem of aggregation

Despite all self-praise in the literature (Blanchard, 2000, Woodford, 2009), is not easy to say whether the NNS framework is good or not. Logical consistency and empirical relevance are the standard criteria for analytical power as well as for empirical capabilities. The specific norms in the application of these criteria to various disciplines and sub-disciplines vary. In the case of NNS macroeconomics the dividing lines between consistency and relevance are not always clear, neither in praise nor in rejection of its apparatus. Its proponents argue that the NNS is highly consistent, because it is rigorously modeled in terms of the DSGE methodology. The strategy of the NNS is based on two main pillars: on one side the aim is to minimize the frictions that are required to reproduce Keynesian results - in terms of persistent real effects of monetary policy - and Wicksellian results - in terms of interaction of interest and prices - in a rigorous framework with intertemporal optimization, forward-looking behaviour and continuously clearing markets. On the other side, it is considered essential to build structural - rather than purely statistical models - whose parameters do not change substantially when policy changes (Lucas, 1976). The claim is that the DSGE framework is capable of rigorously reproducing observable phenomena and to provide a microeconomically well-founded base for the design of optimal policy rules, since it is amenable to welfare analysis. Another claim is that NNS research is empirically highly relevant because these models do seem to have done fairly well in empirical applications, at least for some time. If standard NNS models are not directly capable of replicating the behaviour of the relevant time series, further frictions and complication can easily be added (Mankiw and Reis, 2003; Blanchard and Galí, 2005).

Critics, on the other hand, point out loose ends in the basic NNS structures that imply serious logical flaws, which naturally also get in the way of serious empirical work. Indeed, the current limbo of the NNS comes at the price of some *ad-hocery* and

other shortcomings that have been criticized by way of many papers (Boianovsky and Trautwein, 2006b; Laidler, 2006; Mazzocchi et al., 2009). Some of these ad-hocery and weaknesses might be refined or made redundant in some version of the NNS, but some of it are indispensable for intertemporal equilibrium modeling of the current kind. Let us briefly analyze the main issues that characterize the NNS.

First, there are no proper theoretical foundation of monetary control in a cashless economy with “perfect financial markets”. Most of the general money supply literature is not explicit about the reasons for the existence of a positive quantity of money in a general equilibrium framework. While the old Neoclassical Synthesis use the assumption of an exogeneous money supply, the NNS works without any liquidity preference theory of interest rate. Despite the simplicity of Woodford’s conclusions, there are doubts on the fact that central bank can really take control of interest rates and determine the development of prices in a cashless economy. As Boianovsky and Trautwein (2006b) pointed out, in an perfect competition environment with complete financial markets like in Woodford’s fashion, other riskless nominal assets are perfect substitutes for money, so the law of one price holds. Therefore the central bank is not price-setter, as Woodford claims, but price-taker. The only way to support Woodford’s conclusion¹⁵ is to assume that there are friction that make all other assets imperfect substitutes of the base money and gives the central bank the power to vary its price and quantity at will. But with this implicit assumption the model is no more free of monetary frictions as Woodford wanted. And if we want to maintain the frictionless hypothesis, we have to admit that central bank is not able to control interest rate.

Second, there have been many criticisms also to the mechanisms that have been chosen to introduce nominal rigidities in NNS models. The first models developed in the early nineties (Mankiw and Romer, 1991) used a price-setting mechanism based on the so-called *small menu costs* theory (Mankiw, 1985). Yet, with this trick the real effect of monetary policy would be eligible only if the shock was of modest entity. In fact, if the shock was large, firms would prefer to adjust their prices instead of their quantities, which would imply an increase in capital stock. Moreover, the justification given by the small menu costs theory does not seem fairly strong: printing a new catalog requires only a good database in the computer. Nevertheless, if these restrictive conditions hold, they

¹⁵The whole Woodford’s argument is based on the idea that the the central bank is in a special situation: indeed it is an issuer of liabilities that promise to pay only additional units of its own liabilities. This allows the central bank to fix both the nominal interest yield on its liability and the quantity of them in existence. Nevertheless this argument is not believable: in Woodford’s model the liabilities of the central bank play only the role of unit of account, not the role of a means of payment.

are not however enough. In fact it is not clear why these procedure has not be applied to all the firm's decisions, and only to the price setting. Finally, empirical evidence shows that small nominal frictions determine price rigidity only with non plausible parametric values (Ball et al., 1988; Ball and Romer, 1990; Jeanne, 1998)¹⁶. For these reasons, in almost all the models developed in the last fifteen years has been decided to adopt the Calvo-pricing. Although this price-setting mechanism is totally unrealistic and not well microfounded, it is very popular in the NNS view of monetary theory. But it should be noted that it is plausible only in a low inflation environment, thus it is totally useless in the analysis of accelerating or persistently high inflation. Moreover the drawbacks of the Calvo pricing mechanism are related also to the empirical relevancy: as Eichenbaum and Fisher (2004) pointed out, the postwar U.S. time series show a strong evidence against the standard Calvo model. Only if they allow for a lag between the time that firms re-optimize and the time that they implement their new plans, the model is no longer rejected (Christiano et al., 2001)¹⁷.

Third, the NNS is built on the assumption of forward-looking behaviour of the private sector. As Caballero (2010) and De Grauwe (2010) pointed out, the NNS approach confuses the precision it achieved within its own narrowly defined framework with the precision it achieved about the real world. Presuming intertemporal optimization as aggregate behaviour is not uncontroversial: in particular, it becomes problematic when a single agent's dynamic optimization behaviour is posited - as in the representative agent NNS model - also to hold for the aggregate behaviour¹⁸. Aggregate relationships will not be the same form as those for an individual agent and will typically involve other features of the distribution of the micro variables than just averages. As Keynes (1936, ch. 24) warns us, individual optimal choices do not necessary result in socially preferred outcomes. Social aggregate choice may be needed to complement individual behaviour. General equilibrium involves the interaction of many heterogenous individual agents, subject to correlated shocks: even if microeconomic parameter were structural, their aggregation may make their macro analogues non-structural (Fernandez-Villaverde and Rubio-Ramirez, 2007)¹⁹. The usual shorthand is to assume that random errors of the

¹⁶Because of this weakness, usually economists combine nominal and real rigidity, especially on the labour market (Kiley, 1997; Blanchard and Galí, 2005; Bratsiotis and Martin, 2003).

¹⁷Another possibility is to assume that prices are set optimally one period in advance by a fraction of sellers (with the other flexible).

¹⁸A further problem that arises when intertemporal decision framework is applied to macroeconomics is of course due to the accuracy of the solution methods used when moving toward empirical application of large-scale models. However, this issue is beyond the scope of this chapter.

¹⁹Another key point is to understand whether any instability is a response of policy interventions.

individuals cancel out across agents. This requires that individual errors to be cross-sectionally independent or at least only weakly correlated. This assumption is however contradicted by numerous empirical studies that show that the dynamic times-series properties of the aggregate variables can be fundamentally different from those of the underlying micro units (Pesaran and Chudik, 2011).

Even if we ignore this shortcoming, we have to consider that the main problem with all the models that assume forward-looking behaviour is that they attribute extraordinary cognitive capabilities to individual agents. Intertemporal optimization calculations typically require expectations far into the future and survey measures of distant expectations are rarely available. The shorthand typically used by NNS is to assume that agents have rational expectations. According to this assumption the subjective characterization of uncertainty as conditional probability distributions will coincide with the associated objective probability outcomes. Of course, the rational expectation hypothesis is mathematically elegant and allows model consistent solutions (Blanchard and Kahn, 1980), but it requires private agents to know or learn the true conditional probability distributions (Fuster et al., 2010). This assumption is problematic when agents need to form expectations about the expectations of others, as in Keynes's beauty contest. More in general, many economic and financial processes are not stationary and ergodic as the rational expectation hypothesis required, but are continually affected by technological, political and institutional changes which are largely unpredictable. Thus the rational expectations hypothesis should be use with great caution (Hansen and Sargent, 2008).

1.5.2 Information problems and coordination among economic agents

Closely related to cognitive limitations in the definition of individual plans, there is the problem of information of private agents and policy-makers, especially the central bank. These weaknesses also arise due to poor theoretical accuracy with which the NNS has been built. As pointed out by Boianovsky and Trautwein (2006b) the definition of Non-Accelerating Inflation Rate of Interest (NAIRI) and of Non-Accerelating Inflation Rate of Output (NAIRO) seems to be very confused. The problem arises especially with the introduction of the monopolistic competition and sticky prices in DSGE models. In this type of models, in fact, we can identify at least three definitions of the level of output (and thus of interest rate). There is a level of output that is compatible with a regime of

There is little evidence that structural breaks can be attributed solely to macroeconomic policies.

perfect competition and flexible prices, y_t^{PC} . There is another level that is compatible with a regime of monopolistic competition and perfect flexible prices, y_t^N . Finally there is the actual output, i.e. the level of output compatible with monopolistic competition and staggered-prices, y_t . In particular it is unclear whether nominal rigidities - and the underlying pricing mechanisms - are part of the definition of natural rate or not²⁰. The definition of the benchmark is critical to determine the type of economic policy to be applied. More specifically, the problem to be solved is to understand what should be the measure of the output gap (and the interest rate gap) relevant for the implementation of monetary policy. With reference to what I wrote above, it is unclear whether the measure of the output gap should be $\hat{y}_t = y_t - y_t^{PC}$ or $\hat{y}_t = y_t - y_t^N$. It is a problem that occurs even when we pass to analyze models with endogenous determination of the capital stock like that presented in the previous section. In that framework the capital stock is no longer anchored to its steady state level, but it is a function of past monetary policy when prices were sticky (Trautwein and Zouache, 2009). The nominal rigidity generated by the Calvo-pricing does not only influence the actual output but also the potential output. We can distinguish now an equilibrium rate compatible with the capital stock that would exist if prices had always been flexible in the past²¹ and an equilibrium rate with a state-contingent capital stock dynamics. Using the latter definition, the natural rate of interest is not an attractor for the market rate of interest, but it is determined by other factors influenced by monetary policies. Moreover, by using this new benchmark it is not clear why policy-induced changes in capital stock could not be considered Pareto-superior ex-post²².

Even if we neglect these problems of the definition of the NAIRI and the NAIRO, there is the undue neglect of central banks' problems with information about these two

²⁰A good representation of the confusion on this point can be noticed in Woodford's book (2003). Indeed he defines first the natural rate of output and interest as the equilibrium of real output and real rate of return in the case of perfectly flexible prices. But he said also that the "*the nominal rigidities are taken to be an institutional fact, just like the available production technology*" (Woodford, 2003, p. 7). In other words, in some part of the book Woodford seems to support the traditional RBC view, according to which the natural rate of output and of interest are given by consumer's preferences and producer's technologies and therefore represent the optimal and efficient dynamic paths of real output and interest that we could obtain with perfectly flexible prices. On the contrary, in other part of his work Woodford suggests that the rigidities can be considered as part of the natural rate definition.

²¹Woodford (2003, ch.5) defines this measure "constant-capital natural rate of output", i.e. the real output and interest that would be if prices were flexible and the capital stock did not vary from its steady-state level.

²²For example, an expansionary monetary policy, which is not optimal *ex-ante*, could help to enlarge the output of consumption goods, and therefore could be considered optimal *ex-post* (Trautwein and Zouache, 2009).

key variables. Skepticism about the use of the natural rates for monetary policy was largely prevailing in the past. Wicksell himself (1898a) thought that the natural rate is inherently unobservable and would be difficult to measure in practice²³. Keynes was even more radical, casting doubts on the existence itself of a single general equilibrium rate of interest and output (1937a; 1937b). Friedman still made the point when he linked the natural rate of unemployment to the natural rate of interest in his Presidential Address (1968, p.8), but he also warned that attempts at conducting monetary policy with reference to natural rates might be fallacious. More recently Blinder (1998) states that the natural rate of interest is “*difficult to estimate and impossible to know with precision. It is therefore most usefully thought of as a concept rather than as a number, as a way of thinking about monetary policy rather than a basis of mechanical rule*”. A growing literature shows that wrong information may seriously destabilize the system (Orphanides and Williams, 2002a, 2006; Primiceri, 2006; Tamborini, 2010b). 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. From an empirical point of view, both the NAIRI and the NAIRO are thus unobservable. Their estimations are not straightforward and are associated with a very high degree of uncertainty. That is why it is still difficult to understand what the NAIRI and NAIRO really are (Laidler, 2011). In any case economists have increasingly devoted attention to developing estimation strategies for both the variables. Nevertheless there is not a consensus on the estimation technique and on the determinant of these two rates.

As for the interest rate, the simplest approach is to assume that the NAIRI is equivalent to the trend real rate of interest. The papers consistent with this view (Basdevant et al., 2004; Gnan and Ritzberger-Gruenwald (2005); Cuaresma et al., 2004; Cour-Thimann et al, 2004; Larsen and McKeown, 2004) typically make use of the Kalman filter or other filtering techniques to split the actual real rate into a trend (the natural rate of interest) and a cyclical component (the real rate gap). However, these models do not necessarily contain judgements about the determinants of the NAIRI.

²³Wicksell argued that the central bank should aim to maintain price stability, which in theory could be achieved if the interest rate were always equal to the economy’s natural rate of interest. However, recognizing that the latter is merely an abstract, unobservable concept, he noted: “*This does not mean that the bank ought actually to ascertain the natural rate before fixing their own rates of interest. That would, of course, be impracticable, and would also be quite unnecessary*” (Wicksell, 1898a, pp. 82-84).

Rather, this approach is closer to a pure statistical measure and may be reasonable over periods when inflation and output growth are stable, but leads to substantial biases when output or inflation varies significantly. Therefore, the interpretation of the natural real interest rate in this context is likely to be more relevant in a “shorter” time perspective and consider more the effect of monetary policy on the determination of the natural rate path²⁴.

A more robust approach is to combine statistical tools with structural macroeconomic modeling techniques. A group of economists which includes Giammarioli and Valla (2003), Mésonnier and Renne (2004), Neiss and Nelson (2001) and Sevillano and Simon (2004) associate the fluctuation in the NAIRI with the evolution of real fundamentals such as determinants of trend GDP growth and preferences. These variables are typically stable in the short/medium run, but may display some variation in the longer run. Therefore the natural interest rate should also be relatively stable in the short run, and it should be considered in a long-run perspective. However also the econometric results obtained with these specifications are not very precise and there is very high uncertainty around the estimate of the level of the natural rate of interest. Clark and Kozicki (2005) analyze the difficulties in estimating today’s NAIRI based on the contemporaneous data initially released historically (the so called *real-time* estimates) and conclude that such estimates “*will be difficult to use reliably in practical policy applications*”. A third method extracts the natural rate of interest from the financial market indicators (ECB, 2004) or from a money demand function which depends on the expected natural rate of interest (Andres et al., 2009). Comparing the methods, Caresma et al. (2005) conclude that the differences in levels and volatility are big enough to take the results with caution.

More generally, all the techniques show at least three major kinds of difficulties that discourage the use of such estimates for the conduct of monetary policy. First, we can observe the data only up to today. Thus the estimate of the NAIRI based on data that are available today will be different from the estimate we will make when we have data beyond today because the latter will take into account future data over next periods. The discrepancy between the two estimates could be as large as one to two percentage points. Moreover, macroeconomic data are often revised, and sometimes the revision can be quite substantial. As pointed out by Clark and Kozicki (2005) these

²⁴For instance, inflation was rising during most of the 1970s, suggesting that the trend of the interest rate was, in fact, well below the natural level. Likewise, inflation fell rapidly in the early 1980s, suggesting that the average interest rate was much higher than the natural level.

mistakes could be as high as one to two percentage points, depending on the size of the data revisions. Lastly, the estimates of the NAIRI are particularly sensitive to model specification: these differences can be as large as two percentage points. The previous President of the Deutsche Bundesbank Axel Weber was even more pessimistic when he quoted Parker's: "*Estimation error becomes policy error, and stabilization policy becomes destabilizing*". His own conclusion was: "*one cannot judge the usefulness of the natural rate of interest for monetary policy purposes without taking into account the serious problems that accompany its measurement and estimation. As has been pointed out, these problems are severe and comprise a considerable degree of data as well as model uncertainty*" (Weber, 2006, p. 9)

These and other more important problems may also be noted with regard to the estimate of the NAIRO. It is doubtful whether some of the fundamentally retrospective empirical procedures often used to determine potential - such as univariate filter-based methods - can be appropriately applied in the context of a genuinely forward-looking concept (i.e. the future growth perspectives of an economy measured in terms of potential output). It is also doubtful whether labour input in production function-based methods can be reliably projected into the future given that such volumes are influenced in their turn by changes in labour market structures, technological trends or macroeconomic developments (Hauptmeier et al., 2009).

Another important weakness is that most of the NNS models are focused on the analysis of the functioning of a closed economy, though there have been some extensions to two block structures and small open economy versions (Benigno, 2002; Galí and Monacelli, 2002). Moreover the NNS theory naturally extends to financial variables, since the consumption Euler equation - which is the centre of the DSGE framework - is also the basis for most of the finance theories. However, the NNS model have typically been restricted not to cover financial variables such as long term interest rates, equity prices and exchange rates. These lack do not allow to discuss the effects and the relations between financial market and the real economy. As recognized by Robert Lucas "[...] *the problem is that the new theories, the theories embedded in general equilibrium dynamics [...] do not let us think about the US experience in the 1930s or about financial crises and their consequences [...]. We may be disillusioned with the Keynesian apparatus for thinking about these things, but it does not mean that this replacement apparatus can do it either*" (Lucas, 2004). For this reason in recent years new models have been designed to take stock of pre-crisis debates and to overcome various limitations that emerged from theoretical weaknesses as well as from empirical

reconstructions and stylized facts of boom-bust cycles (Christiano et al., 2010a).

Despite these efforts in strengthening the NNS models, it still leaves us the need of explanations for the recent *dot.com* boom and bust, for the subprime mortgage crisis, for the stock market crash of 1929 which ushered in the subsequent Great Depression, for the collapse of the Japanese “bubble economy” and for many others similar episodes. None of these crises was precipitated by any obvious exogenous shock, neither by attempts to maintain an unsustainable exchange rate, nor, crucially, were they heralded by a significant burst of broadly-based price inflation (Laidler, 2009). A possible way out is to be found in those elements of the inter-war literature whose often disparate components are linked by what Leijonhufvud called “the Wicksell connection” (Leijonhufvud, 1981). Even if Keynes and many others saw that the coordination of saving and investment decisions as the core problem of macroeconomic theory, in the NNS the problem of intertemporal coordination drifted so far out of the focus as to be virtually forgotten. Indeed the NNS framework is set in continuous intertemporal equilibrium and cannot deal with imbalances of planned saving and investment, nor can it deal with financial intermediation and its effects on budget constraints in the long run. Since it assumes financial market to be perfect, the model finds its equilibrium at the natural rate of interest as determined by the forces of productivity and thrift that equate saving and investment at full-employment of resources. Deviations from the optimal growth path of the economy are essentially explained in terms of sticky-prices, sticky-wages or other imperfections in the goods or labour markets.

As soon as the banking system comes into play all these arguments no longer necessarily hold. One important reason is that intermediaries act with limited information about the natural rate, which is a reason why deviations of the market real interest rate from the natural rate may ever arise. In the NNS, whenever the market real interest rate deviates from the natural rate, households reallocate resources towards present/future consumption along a new intertemporal equilibrium path with an equivalent impact on aggregate demand. This is a consistent transmission mechanism as long as there are no capital goods, but where there are capital goods to be purchased by means of money and there is a market for loanable funds made by independent borrowers and lenders, the consequence of the market real interest rate on loans being higher/lower than the natural rate is that households wish to save more/less whereas firms wish to invest less/more: neither side of the market can achieve intertemporal equilibrium of plans. Thus the problem is that the banking system as a whole might both expand/reduce the total nominal purchasing power in the economy and allocate it at terms that differ from

those dictated by full-employment saving-investment equilibrium. Over-investment or over-saving allowed for by imperfect bank intermediation are therefore the main explanations of price changes and of the business cycles. As Borio and Disyatat (2011) pointed out the lack of discussions of these elements in the NNS models not only has led to a failure to consider the distinguishing characteristics of a monetary economy, but also has been the main contributing factor to the recent financial crisis. Yet ruling saving-investment imbalances out of the theory constitutes a major theoretical weakness of the NNS (Van der Ploeg, 2005).

1.6 Conclusion

The NNS can be regarded as the newly established macroeconomic consensus. Blanchard (1997, p.290) correctly observed that almost all economists now work within a framework that combines intertemporal optimization, imperfect competition and nominal rigidities. The NNS is based on a system of three building blocks that determines the short-run dynamics of output, inflation, interest rates and other variables. Most attention is confined to the study of small fluctuations around a deterministic steady state, thus the model is presented as a log-linear approximation of the conditions for intertemporal general equilibrium. Despite the problems and weaknesses that we have highlighted in this chapter, the NNS has undoubtedly provided a strong enough structure that can be easily compared with the RBC models developed during the eighties. After a period in which we observed the rise of separate field of murky ad-hocery, macroeconomics seems to return back to a proper extension of a standard general equilibrium theory. The latter can be modified in many ways to cater to the different sub-disciplines, such as labour economics, industrial organization. In this way it become easier to connect macroeconomics with all the other disciplines, modeling specific frictions into a standard framework that help to explain the usual macroeconomic pathologies and identify the political instruments and time consistent strategies to deal with them. Thus the NNS started investigating a new class of models in which agents optimize intertemporally in economies with some non-Walrasian features.

While the NNS has proved quite permeable with regard to the explanation of the nominal and real rigidities in product and labour markets, the same can not be said for the financial market, which remains perfectly Walrasian. This lack makes inadmissible the claim of many economists to be a kind of successor of the great founders of modern macroeconomic thought, not only Keynes but also Wicksell. In fact, the existence of

intermediaries between savers and investors, which was the main feature of the Wicksellian literature, can only be due to some departure from the Walrasian paradigm. Moreover, all three actors on the capital market act with limited information, which is the reason why deviations of the market interest rate from the natural rate may arise. In other words, the main contention of the old macroeconomics was saving-investment imbalances - i.e. capital market failures and intertemporal disequilibrium in modern parlance - that are notably absent from the NNS²⁵.

The most serious consequence of this deficiency is that the NNS did not let us think about the financial crisis and the macroeconomic imbalances that were forming in the years of the Great Moderation. Analyses in a Wicksellian vein of 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 that has probably played a role in driving monetary policy onto a wrong track (Borio and Lowe, 2002). The lack of attention to exchange rates, to the stock market, to the financial intermediaries and to the real estate led to the progressive loss of control of the entire system. In this situation even a Taylor rule - whether optimal or adaptive - may break down: the central bank discovers whether his market rate is too low or too high by the price level starting to rise or fall, and he can then adjust his rate accordingly. The problem is that this crucial feedback loop can be short circuited by the arising of a saving-investment imbalances. The trouble with inflation targeting in present circumstances is that a constant inflation rate give no information about whether the monetary policy is right or not. And a wrong monetary policy allows the financial imbalances to grow without end.

The failure of the NNS framework leaves open the question of what can be done with models that exclude in advance the possibility of any pathology in the working of the market system, and certainly of any collapse in the trading system to the extent that we have recently encountered. NNS models convey a Panglossian view of the working of the economy as they rule out the possibility that markets can fail and that agents may find themselves in a state where they are unable to achieve their optimizing plan (De Vroey and Malgrange, 2011). When the economy is in a state of plain sailing, this neglect is admissible, but it is no longer justifiable when the economy shows signs of

²⁵In comparison with the *NNS triangle* of imperfect competition, sticky prices and intertemporal optimization, Mazzocchi et al. (2009) propose a *Wicksell-Keynes triangle* that can thus be described by the key words “imperfect capital market”, “interest-rate misalignments” and “intertemporal coordination”.

collapse. Laidler (2006) has rightly summarized by saying that NNS framework can be applied only to “fair weather conditions”.

Exit routes, however, are not easy to find. The claim of the critics of the NNS have prompted further developments in two main direction. The first - although consider the DSGE framework a “too big to fail” industry that will survive the present crisis due to vested interest (Leijonhufvud, 2009) - thinks that is futile to try reinterpret Keynes and other earlier macroeconomists in terms of models that share a number of features with current DSGE modeling²⁶. The second instead investigates whether and to what extent a reconsideration of those original ideas may improve our understanding and policy of business cycles sticking as closely as possible to the object of criticism, namely the NNS (Boianovsky and Trautwein, 2006b; Tamborini, 2010b; Mazzocchi et al., 2009; Mazzocchi, 2010). As long as there is not a plausible alternative in terms of a unified analytical model, it should still be a fruitful exercise to criticize the current consensus by their own standard and thus help them to become skeptical enough to try to make progress along different lines of thinking.

Appendix: the NNS model

In this section we fully derive the NNS model with endogenous capital stock.

The Households A representative household maximizes expected discounted utility (Mas-Colell et al., 1995; Kreps, 1990)²⁷:

$$E_t \sum_{k=0}^{\infty} \beta^k \left(\frac{C_t^{1-\sigma}}{1-\sigma} + \frac{1}{1-\gamma} \left(\frac{M_t}{P_t} \right)^{1-\gamma} - \frac{N_t^{1+\phi}}{1+\phi} \right) \quad (1.8)$$

where β is the discount factor, $\sigma < 1$ denotes household’s relative risk aversion, $\phi > 0$ can be interpreted as the inverse of the aggregate labour supply elasticity, $\gamma < 1$ is the inverse of the semi-elasticity of the household’s demand for real balances with respect to the nominal interest rate, N_t is the number of hours worked in period t , $\frac{M_t}{P_t}$ are the real money balance and C_t denotes the time t consumption aggregator (Dixit and

²⁶During a recent presentation at the London School of Economics, Paul Krugman pointed out that “most work in macroeconomics in the past 30 years has been useless at best and harmful at worst”.

²⁷This type of utility function - the so called CRRA - has important characteristics. In particular the marginal utility of consumption $\frac{\partial U}{\partial C_t} = C_t^{-\sigma}$, the intertemporal marginal rate of substitution $\text{IMRS} = \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma}$.

Stiglitz, 1977). The latter has the following expression:

$$C_t = \left[\int_0^1 C_t(i)^{\frac{\varepsilon-1}{\varepsilon}} di \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (1.9)$$

The price level P_t has the following expression:

$$P_t = \left[\int_0^1 P_t(i)^{1-\varepsilon} di \right]^{\frac{1}{1-\varepsilon}} \quad (1.10)$$

Cost minimization by households implies that:

$$\max C_t = \left[\int_0^1 C_t(z)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}} \quad (1.11)$$

subject to:

$$\int_0^1 P_t(z)C_t(z)dz = Z_t \quad (1.12)$$

where Z is the income. By setting the Lagrangian and after some manipulations we get:

$$C_t(i) = \frac{P_t(i)^{-\varepsilon}}{P_t} C_t \quad (1.13)$$

which is the demand for good i . From this allocation it follows that:

$$\int_0^1 P_t(i)C_t(i)di = P_t C_t \quad (1.14)$$

The maximization problem will be thus the following:

$$\max E_t \sum_{k=0}^{\infty} \beta^k \left(\frac{C_t^{1-\sigma}}{1-\sigma} + \frac{1}{1-\gamma} \left(\frac{M_t}{P_t} \right)^{1-\gamma} - \frac{N_t^{1+\phi}}{1+\phi} \right) \quad (1.15)$$

subject to a sequence of budget constraints:

$$C_t \leq \frac{W_t}{P_t} N_t + \Pi_t + \frac{M_t - M_{t-1}}{P_t} - \frac{\frac{1}{R_t^n} B_t - B_{t-1}}{P_t} \quad (1.16)$$

where B_t denote the nominal payoffs associated with the portfolio held at the end of period $t - 1$. Moreover P_t gives the price index, W_t is the nominal wage as of period t , and Π_t denotes profits resulting from ownership of firms.

Let me define the Bellman equation as follows:

$$v\left(\frac{M_{t-1}}{P_t}, \frac{B_{t-1}}{P_t}\right) = \max \left[U_t + E_t \beta v\left(\frac{M_t}{P_{t+1}}, \frac{B_t}{P_{t+1}}\right) \right] \quad (1.17)$$

subject to (1.16). The FOCs of the household's maximization problem are as follows:

$$C_t^\sigma N_t^\phi = \frac{W_t}{P_t} \quad (1.18)$$

$$C_t^{-\sigma} = E_t \left\{ \frac{P_t}{P_{t+1}} \beta C_{t+1}^{-\sigma} \right\} + \left(\frac{M_t}{P_t} \right)^{-\gamma} \quad (1.19)$$

$$\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} = R_t \quad (1.20)$$

The first and the second equations are the optimality condition for labour supply and the demand for real balances. The third equation is the standard Euler equation for consumption. Finally, let us note that the nominal interest rate can be expressed also in real term as $R_t = R_t^n \frac{P_t}{P_{t+1}}$. Substituting (1.20) into the (1.19) we get:

$$C_t^\sigma N_t^\phi = \frac{W_t}{P_t} \quad (1.21)$$

$$\frac{M_t}{P_t} = \left(1 - \frac{1}{R_t^n} \right)^{-\frac{1}{\gamma}} C_t^{\frac{\sigma}{\gamma}} \quad (1.22)$$

$$\beta \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} = R_t \quad (1.23)$$

The Firms Each firm uses both labour N_t and capital K_t to produce output Y_t according to the following constant return to scale production function:

$$Y_t(i) = K_t(i)^\alpha N_t(i)^{1-\alpha} \quad (1.24)$$

where parameter α is the capital share. Each firm i makes an investment decision at any point in time with the resulting additional capital becoming productive one period after the investment decision is made. Therefore the law of motion of capital at the

firm level is given by the following equation:

$$K_{t+1}(i) = (1 - \delta)K_t(i) + I_t(i) \quad (1.25)$$

where $I_t(i)$ denotes the amount of composite good purchased in period t by firm i and δ is the depreciation rate. It is natural to consider how aggregate demand is determined since it affects each firm's demand and therefore the price setting decisions of price setters. Let us assume that the investment good is an aggregate of all the goods in the economy with the same constant elasticity of substitution as in the aggregate consumption²⁸:

$$Y_t^d = \left[\int_0^1 Y_t^d(i)^{\frac{\epsilon-1}{\epsilon}} di \right]^{\frac{\epsilon}{\epsilon-1}} \quad (1.26)$$

Cost minimizing by firms and households implies that demand for each individual good i in period t can be written as follows²⁹:

$$Y_t^d(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\epsilon} Y_t^d \quad (1.27)$$

Knowing the law of motion of the capital (1.25), the aggregate investment demand $I_t = \int_0^1 I_t^d(i)$ and the aggregate capital stock $K_t = \int_0^1 K_t^d(i)$, the total demand is given by:

$$Y_t^d = C_t + I_t \quad (1.28)$$

Finally, let us assume that firms face a convex adjustment cost of changing their capital holdings³⁰. Given $K_t(i)$, the amount of composite good $I_t(i)$ that has to be purchased by that firm at this point in time in order to have a capital stock $K_{t+1}(i)$ in place in the subsequent period is given by:

$$I_t(i) = I \left(\frac{K_{t+1}(i)}{K_t(i)} \right) K_t(i) \quad (1.29)$$

where $I(1) = \delta$, $I'(1) = 1$ and $I''(1) = \epsilon_\psi$. Parameter δ denotes the depreciation rate, whereas parameter ϵ_ψ measures the capital adjustment cost in a log-linear approxima-

²⁸This implies that firms buy the different capital goods in the same proportion as in the consumer aggregate.

²⁹Proof is omitted by is available upon request

³⁰Example of such costs are the costs of installing the new capital and training workers to operate the new machines (Eisner and Strotz, 1963; Lucas, 1967).

tion to the equilibrium dynamics³¹.

Firms set prices *à la Calvo*, i.e. in each period only for a fraction $1 - \theta$ of enterprises (where $0 < 1 - \theta < 1$), randomly selected, it is possible to adjust the price in a period, while the remaining θ firms post their last period's price. With probability θ^k a price that was chosen at time t will still be posted at time $t + k$. When setting a new price $P_t^*(i)$ in period t firm i maximizes the current value of its dividend stream over the expected lifetime of the chosen price. Formally, given $K_t(i)$, price setters choose contingent plans for $\{P_{t+k}^*, K_{t+k+1}(i); N_{t+k}(i)\}_{k=0}^{\infty}$ in order to solve the following problem:

$$\max_{P_t^*(i); I_t(i)} E_t \sum_{k=0}^{\infty} \left\{ \frac{1}{R_{t+k}} [Y_{t+k}^d(i) P_{t+k}(i) - W_{t+k} N_{t+k}(i) - P_{t+k} I_{t+k}(i)] \right\} \quad (1.30)$$

subject to:

$$Y_{t+k}^d(i) = \left(\frac{P_{t+k}(i)}{P_{t+k}^*} \right)^{-\epsilon} Y_{t+k}^d \quad (1.31)$$

$$Y_{t+k}(i) = K_{t+k}(i)^\alpha N_{t+k}(i)^{1-\alpha} \quad (1.32)$$

$$I_{t+k}(i) = I \left(\frac{K_{t+k+1}(i)}{K_{t+k}(i)} \right) K_{t+k}(i) \quad (1.33)$$

$$P_{t+k}(i) = \begin{cases} P_{t+k+1}^*(i) & \text{with probability } 1 - \theta \\ P_{t+k}(i) & \text{with probability } \theta \end{cases} \quad (1.34)$$

The implied FOC for capital accumulation is the following:

$$\frac{dI_t(i)}{dK_{t+1}(i)} P_t = \frac{1}{R_t^n} E_t \left[\Lambda_{t+1}(i) - \frac{dI_t(i)}{dK_{t+1}(i)} P_{t+1} \right] \quad (1.35)$$

where $\Lambda_{t+1}(i)$ denotes the nominal marginal savings in firm i 's labour cost associated with having one additional unit of capital in place in period $t + 1$. The intuition behind this equation is that the marginal cost of installing an additional unit of capital at time t (including adjustment costs) is equalized to the expected discounted marginal contribution to the firm's value associated with having that additional unit of capital in place at time $t + 1$. The latter is given by the marginal return from using it for

³¹Eichenbaum and Fisher (2004) interpret parameter ϵ_ψ as the elasticity of the investment to capital ration with respect to Tobin's q .

production³² - $\Lambda_{t+1}(i)$ - and selling the remaining capital after depreciation.

The FOC for the price setting is given by:

$$\sum_{k=0}^{\infty} \theta^k \frac{1}{R_t^n} E_t \{ Y_{t+k}^d(i) [P_t^*(i) - \mu S_{t+k}(i)] \} = 0 \quad (1.36)$$

where $\mu \equiv \frac{\varepsilon}{\varepsilon-1}$ is the frictionless mark-up over marginal costs and $S_t(i)$ denotes the nominal marginal cost. Equation (1.36) is the familiar FOC implied by the Calvo model: optimizing price setters behave in a forward-looking manner, i.e. they take into account not only current but also future expected marginal costs in those states of the world where the chosen price is still posted. The only non-standard feature is that capital affects labour productivity and hence firm's marginal cost.

Central bank Monetary policy determines M_t . Let me consider a simple Taylor rule like the following:

$$R_{t+1}^n = R^n \left(\frac{P_t}{P_{t-1}} \right)^{\gamma_\pi} \left(\frac{Y_t}{Y_{t-1}} \right)^{\gamma_y} \quad (1.37)$$

where R^{n*} is the steady state real interest rate (natural rate), Y_t^* is the NAIRO and ε_t^r . Note that the (1.37) indirectly determines M_t (see eq. (1.22)).

Equilibrium Clearing of the market requires the following conditions:

$$N_t = \int_0^1 N_t(i) di \quad (1.38)$$

$$Y_t(i) = Y_t^d(i) \quad (1.39)$$

$$Y_t = C_t + I_t \quad (1.40)$$

where $I_t = \int_0^1 I_t(i) di$, $K_t = \int_0^1 K_t(i) di$ and auxiliary variable $\tilde{Y}_t \equiv K_t^a N_t^{1-a}$ ³³

³²As Woodford (2003) pointed out, the relevant measure of the marginal return to capital is the marginal savings in a firm's labour cost: firms are demand constrained and hence the return from having an additional unit of capital in place results from the fact that this allows to produce the quantity that happens to be demanded using less labour.

³³The difference between \tilde{Y}_t and the aggregate output in the economy $Y_t = \left(\int_0^1 Y_t^{\frac{\varepsilon-1}{\varepsilon}} d(i) \right)^{\frac{\varepsilon}{\varepsilon-1}}$ is of second order. We can safely ignore it for the purpose of log-linear approximation to the equilibrium dynamics.

Log-linear version We restrict our attention to a log-linear approximation to the equilibrium dynamics around a steady-state with zero inflation. Lowercase letters represent the logarithm of each variable. The percentage deviation of a variable with respect to its steady state is denoted by a hat, i.e. $\hat{x} = x - \bar{x}$. Thus \hat{x} is the logarithmic deviation from the steady-state.

IS block Let us start with the household's labour supply equation (1.21):

$$\hat{\omega} = \phi \hat{n}_t + \sigma \hat{c}_t \quad (1.41)$$

where $\hat{\omega} = \hat{w}_t - \hat{p}_t$ is the real wage. This is equation (1.4) in the main text. Log-linearizing and rearranging equation (1.23) we get:

$$\hat{c}_t = E_t \hat{c}_{t+1} - \frac{1}{\sigma} (i_t - E_t \pi_{t+1} - \rho) \quad (1.42)$$

where i_t denotes the nominal interest rate and $\pi_t \equiv \log \left(\frac{p_t}{p_{t-1}} \right)$ is the rate of inflation. Finally, the dime discount rate is given by $\rho \equiv -\log \beta$. This is equation (1.2) in the main text.

We log-linearize the FOC for capital accumulation (1.37) and average it over all firms in the economy. Combining the resulting relationship with the (1.42) we obtain the law of motion of the aggregate capital stock (equation (1.3) in the main text):

$$\hat{k}_{t+1} = \frac{1}{1 + \beta} \hat{k}_t + \frac{\beta}{1 + \beta} E_t \hat{k}_{t+2} + \frac{1 - \beta(1 - \delta)}{\epsilon_\psi(1 + \beta)} E_t \hat{\chi}_{t+1} - \frac{1}{\epsilon_\psi(1 + \beta)} (i_t - E_t \pi_{t+1} - \rho) \quad (1.43)$$

where $\chi_t \equiv \frac{\lambda_t(i)}{p_t}$ denotes the average real marginal savings in labour costs. Assuming capital adjustment cost implies that capital is a forward-looking variable.

Finally, let me consider equation (1.42). After invoking equations (1.24), (1.27) and (1.29) we log-linearize the resulting relationship and obtain:

$$\hat{y}_t = \zeta \hat{c}_t + (1 - \zeta) \frac{1}{\delta} \left[\hat{k}_{t+1} - (1 - \delta) \hat{k}_t \right] \quad (1.44)$$

where $\zeta \equiv \frac{\rho + \delta(1 - \alpha)}{\rho + \delta}$ denotes the steady-state consumption to output ratio while the steady-state capital to output ratio is given by $(1 - \zeta) \frac{1}{\delta}$. This is equation (1.4) in the main text.

AS block The inflation equation is derived from averaging optimal price setting decisions and aggregating prices via price index. Following Galí et al. (2001) and Sbordone (2002) we start from the log-linearized real marginal cost S_t at the firm level:

$$\hat{s}_t(i) = \hat{s}_t - \frac{\varepsilon\alpha}{1-\alpha}\hat{p}_t(i) - \frac{\alpha}{1-\alpha}\widetilde{\hat{k}}_t(i) \quad (1.45)$$

where $\widetilde{\hat{k}}_t(i) \equiv \frac{K_t(i)}{K_t}$ and $s_t = \int_0^1 \frac{S_t(i)}{P_t}$. The intuition behind this equation is the following: for a zero capital gap a firm that posts a higher than average price faces a lower than average marginal cost due to the decreasing marginal product of labour (second term). With capital accumulation there is an extra effect coming from the firm's capital stock (last term). Conditional on posting the average price in the economy a firm that has a higher than average capital stock in place faces a lower than average marginal cost. The reason is that the marginal product of labour increases with the capital stock used by the firm.

Invoking equations (1.38) and (1.45), the optimal price of firm i defined as $\widetilde{p}_t^*(i) \equiv \frac{P_t^*(i)}{P_t}$ can be log-linearized as:

$$\widetilde{p}_t^*(i) = \sum_{k=1}^{\infty} (\beta\theta)^k E_t \hat{\pi}_{t+k} + \xi \sum_{k=0}^{\infty} (\beta\theta)^k E_t \hat{s}_{t+k} - \psi \sum_{k=0}^{\infty} (\beta\theta)^k E_t \widetilde{\hat{k}}_{t+k}(i) \quad (1.46)$$

where $\xi \equiv \frac{(1-\beta\theta)(1-\alpha)}{1-\alpha+\varepsilon\alpha}$ and $\psi \equiv \frac{(1-\beta\theta)\alpha}{1-\alpha+\varepsilon\alpha}$. In addition to the usual inflation and average marginal cost terms, the price setting decision depend also on the current and future expected capital gaps over the random lifetime of the chosen price. Woodford (2004) shows that the associated inflation takes the following form (equation (1.5) in the main text):

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa \hat{s}_t \quad (1.47)$$

where κ is a parameter computed numerically. Finally, we note that the following aggregate production function holds up to a first-order approximation (equation (1.6) in the main text):

$$\hat{y}_t = \alpha \hat{k}_t + (1-\alpha)\hat{n}_t \quad (1.48)$$

Monetary policy block Finally, we could close the model using the traditional Taylor rule (1.37) which guarantees the determinacy of the whole system. It gives us the

evolution of \hat{i}_t , given \hat{Y}_t and $\hat{\pi}_t$ from the IS and AS block, respectively.

$$\hat{i}_t = \gamma_\pi \hat{\pi}_t + \gamma_y \hat{y}_t \tag{1.49}$$

This is equation (1.7) in the main text.

Chapter 2

Toward a Macroeconomic model with Investment-Saving Imbalances

2.1 Introduction

Modern macroeconomic models can be traced back to a revolution that began in the 1980s in response to the powerful critique authored by Robert Lucas (1976). The key issue was to build models that were specifically based on the aspects of the economy that were beyond the control of the government. All the relationships among the variables need to be ultimately grounded in fundamental features of the economy production, such as technology and people's preferences, i.e. the so-called "deep parameters"¹.

This revolution has led to the so-called Dynamic Stochastic General Equilibrium (DSGE) models. *Dynamic* refers to the forward-looking behavior of households and firms. *Stochastic* refers to the explicit inclusion of shocks in the analysis. *General* refers to the treatment of the whole economy. Finally, *equilibrium* refers to the constraints and objectives for households and firms that are carefully considered. Another key ingredient of these new models were *rational expectations*. This term means that households and firms form forecasts about the future as if they were statisticians: it does not mean that they are always right but that they statistically cannot make better forecasts given their available information.

The switch to these new macro-models led to a fierce controversy within the field in the 1980s. Users of the new models not only brought a new methodology, but they also

¹Many economists seem to read the Lucas critique as if it implies we can protect against non-invariance simply by applying microeconomic theory. This is a mistake. As pointed out by Debreu (1974), Sonnenschein (1972; 1973), Felipe and Fisher (2003) and many others, there is no reason to believe that macroeconomic aggregates should behave like microeconomic quantities.

had a surprising substantive finding to offer regarding business cycles. They argued that a large fraction of aggregate fluctuations could be understood as an *efficient* response to shocks that affected the entire economy (Kydland and Prescott, 1982; Nelson and Plosser, 1982; Long and Plosser, 1983). This became the core of the Real Business Cycle (RBC) theory. Most of these models rely on some form of large quarterly movements in the technological frontier (Prescott, 1986a; 1986b). Some other models consider collective shocks to workers' willingness to work. Other contributions have large quarterly shocks to the depreciation rate in the capital stock in order to generate high asset price volatilities. The RBC framework uses this notion of shocks only as convenient shortcuts to generate the requisite levels of volatility in endogenous variables. But this assumption leads to the conclusion that most - if not all - government stabilization policies are inefficient.

Despite the formal elegance of these models, the source of disturbances together with the transmission mechanism were patently unrealistic. For a large economy like the United States or the European Union it is implausible for the fluctuations in the efficient level of aggregate output to be as large as the fluctuations in the observed level of output (Calomiris and Hanes, 1995). The rational expectations hypothesis has been attractive because it provides a simple and unified way to approach the modelling of forward-looking behavior in a wide range of settings, but it is also clearly questionable². Even the assumption of frictionless exchange made solving these models easier but also less compelling. In the real world firms change prices only infrequently (Carlton, 1986; Blinder, 1994; Hall et al., 1997), thus many macro models developed during the 1980s were centered on infrequent price and wage adjustment (Fischer, 1977; Taylor, 1980; Mankiw, 1985). These models were often called *sticky prices* or *New Keynesian* models, or NKE (Mankiw and Romer, 1991; Hargreaves-Heap, 1992), and provide a foundation for a coherent normative and positive analysis of monetary policy in face of shocks.

The divide between NKE and RBC still lives in newspaper columns but has largely vanished in the academia. Both camps have won. On the one hand the RBC won in terms of modeling methodology. On the other hand, the NKE has also won because it is generally agreed that some forms of stabilization policy are useful. Along these lines, a new consensus developed in the late 1990s and it was soon dubbed the *New*

²Among other things, the rational expectation hypothesis implies that economists have no social function and that they are the last to learn (Leijonhufvud, 1992). Moreover long-standing research (Hansen and Sargent, 2001, 2008; Sims, 2003) explores the consequences of relaxing the assumption and has proven challenging both conceptually and computationally.

Neoclassical Synthesis, or NNS (Goodfriend and King, 1998; Blanchard, 2000). Like the old Neoclassical Synthesis of Hicks, Modigliani, Samuelson and Patinkin, the NNS tries to link micro- and macroeconomics, using a general equilibrium framework to model some typically Keynesian features³: the RBC part of the model explains the evolution of the potential output, while the transitory deviations from this trend are explained using the sluggish adjustment of prices and wages which were developed in the 1980s by the NKE literature. Like the RBC models, the NNS recognizes that some non-trivial fraction of aggregate fluctuations is actually efficient in nature. Differently from the RBC models, however, the NNS does not consider these fluctuations efficient and desirable and does not think that monetary policy is totally ineffective. In fact, because of the delays in the adjustment of prices and wages, the consequences of real shocks are undesirable. An active economic policy can therefore intervene to reduce these distortions.

There are various versions of the NNS (Rotemberg and Woodford, 1997; Clarida et al., 1999; Romer, 2000). One authoritative contribution is Michael Woodford's *Interest and Prices* (Woodford, 2003), which gives a comprehensive representation of the dynamic interaction between interest rates, price level and output⁴. Requiring only a small number of equations and variables, the model has proved very helpful in deriving certain important principles for the conduct of monetary policy. As reflected in its title, the book pays a respect to Knut Wicksell's work and his theory of the price level⁵. The main aspect of Woodford's contribution, indeed, is a rediscovery of the Wicksellian nominal interest rate in relation to the "natural" interest rate prevailing at full-employment general equilibrium as the pivot of rule-based monetary policy. As pointed out by McCallum (2010), Woodford's model has become the bible for a generation of young scholars and it has dominated monetary economics in the last decade.

³Olivier Blanchard summarizes the standard NNS approach using a metaphor: "*A macroeconomic article today often follows strict, haiku-like, rules: It starts from a general equilibrium structure, in which individuals maximize the expected present value of utility, firms maximize their value and markets clear. Then, it introduces a twist, be it an imperfection or the closing of a particular set of markets, and works out the general equilibrium implication. It then performs a numerical simulation, based on calibration, showing that the model performs well. It ends with a welfare assessment*" (Blanchard, 2008, p.27).

⁴Lucas (2007) argued that NNS models should be reformulated to give a unified account of trends, including those in monetary aggregates. In a similar vein Papademos (2008) and Pesaran and Smith (2011).

⁵In his 1898 treatise (Wicksell, 1898a), Knut Wicksell outlined a theory of price-level determination in which a key role was played by the relationship between the money rate of interest and the natural rate of interest. Likewise in Woodford's book the gap between the actual interest rate and the natural rate represents the key channel through which central bank actions affect the economy.

Some critics (Boianovsky and Trautwein, 2006b; Trautwein and Zouache, 2009; Mazzocchi et al., 2009) have shown that the theoretical structure of the NNS is based on a shaky relationship between the RBC model on one side and a mechanism of price setting which does not depend on excess demand on the other side. At the same time, most of the Wicksellian features that Woodford claims to replicate are notably absent. In particular, the NNS does not consider frictions in the capital market, which generate the first pillar of the Wicksell's view, i.e. bank intermediation among savers and investors. Moreover, there is no room for information problems and the intertemporal disequilibrium which could produce the well-known dynamics of money creation, prices and nominal income, i.e. the so-called *cumulative process*. These weaknesses are not only a matter of history of thought. For instance, they do not allow to discuss the effects and the relations between financial market and the real economy which were the core of the economic crisis of 2008.

The aim of this chapter is to show that there are systematic differences in terms of dealing - or not dealing - with intertemporal disequilibrium, i.e. coordination failures in the market system that have their origin in the capital markets (essentially financial markets) and cannot independently be corrected in the goods or labour markets. Investment-saving imbalances are a logical implication of any theory based on the distinction between market real interest rate and the natural rate. The consequence of a discrepancy between the two rates is that households wish to save more/less whereas firms wish to invest less/more: neither side of the market can achieve the intertemporal equilibrium position. As a result the system exhibits dynamic processes of both output and general price level that deviate from their intertemporal equilibrium values. These gaps persist as long as the one between the market real interest rate and the natural rate persists.

The paper is organized as follows. Section [2.2] presents some basic theoretical issues underlying the NNS and shows that this framework - both in its neo-Wicksellian and other versions - is precariously based on combinations of continuous intertemporal equilibrium under rational expectations with specific concepts of wage and price stickiness, and other assumptions. Section [2.3] presents a dynamic model whereby it is possible to assess, and hopefully to clarify, some basic issues concerning the macroeconomics of saving-investment imbalances. The treatment of the capital market is still only remotely connected with the full-fledged financial structure of the economy, therefore the imbalances are dealt with in a way that focuses on deviation of output and inflation from their intertemporal general equilibrium paths, where the possibilities of

loan defaults and insolvencies are ignored. The modeling strategy sticks as closely as possible to the NNS model, in order to show that a basic model of capital market failures can be developed from the same underlying framework of RBC theory. This choice requires less modifications of the general equilibrium framework than the NNS setup and it helps, on one hand, to identify the limits of the DSGE modeling and, on the other hand, to explore the gains that can be obtained by moving from the NNS framework towards the realm of intertemporal disequilibrium. Section [2.4] discusses some dynamic properties of the model with particular attention to the speed of price adjustment, to the variability of the capital stock and to the inflation expectations. Finally section [2.5] concludes. Proofs are in the Appendix.

2.2 NNS in a Neo-Wicksellian Framework: strengths and weaknesses

Over the last decade a shift has begun away from the Walrasian price-taker models towards a world where firms may be strategic agents. The NNS approach uses the standard tools of New Classical macroeconomics (NCM): consumers, workers and firms are rational, agents maximize their objective function and markets clear. Yet the output of NNS models follows Keynesian lines: the aggregate economy has multipliers, economic fluctuations are not Pareto optimal, and finally government interventions can be effective. Even if business cycles and growth are analyzed within a single framework that is based on Walrasian principles, *“this does not mean that the Keynesian goal of structural modeling of short-run aggregate dynamics has been abandoned. Instead, it is now understood how one can construct and analyze dynamic general equilibrium models that incorporate a variety of types of adjustment frictions, that allow these models to provide fairly realistic representations of both shorter-run and longer-run responses to economic disturbances”* (Woodford, 2009, p. 69). Imperfect competition⁶ is a key assumption in this approach. It opens new channels of influence of monetary policies but also creates the possibility that an increase in output may be welfare improving (Cooper, 2004). Imperfect competition by itself does not create monetary non-neutrality, but its combination with some other distortions can generate potential real effects (Blanchard, 2000).

⁶The NNS models use mainly monopolistic competition as a form of imperfect competition (Blanchard and Kiyotaki, 1987). This choice derives mainly from the belief that monopolistic competition is pervasive in a modern economy.

Among the various version of the NNS, a prominent position is occupied by Michael Woodford's book *Interest and Prices* (Woodford, 2003), which represents a good synthesis of New Classical and New Keynesian ideas. This work contains many references to Wicksell's idea of a pure credit system and his proposal to eliminate inflation by adjusting nominal interest rates to changes in the price level⁷. Since the output and the inflation dynamics are generated by gaps between the natural rate of interest and the market rate, a central bank that controls the latter can close the gap using an appropriate monetary policy. Up to 2008 this contention has become the generally accepted rationale for monetary policy around the world and most monetary authorities use interest rate control to achieve price stability rather than the quantity of money. Such a rules-based approach to policy is discussed at length in the first part of Woodford's book and taken up again at its end. However, Woodford doubts that the original "*Wicksellian theory can provide a basis for the kind of quantitative analysis in which a modern central bank must engage*" (2003, p. 5-6) because it does not conform to modern standards of conceptual rigour, i.e. intertemporal general-equilibrium theory. His book seeks to remedy this shortcoming.

The attention of readers and economists has focused primarily on the basic version of the model (2003, ch. 4). It combines an IS relation in terms of the first-order condition of intertemporal utility maximization with a New Keynesian Phillips curve, based on imperfect competition and price rigidities, and a Taylor rule as reaction function of monetary policy. Woodford points out that his model "*abstracts from the effects of variations in private spending (including those classified as investment expenditure in the national accounts) upon the economy's productive capacity*", therefore the model should be interpreted "*as if all forms of private expenditure were like nondurable consumer purchases*" (2003, p. 242-243)⁸. The preference for a model without endogenous capital stock is often justified on the grounds that capital does not exhibit substantial volatility at business cycle frequencies (McCallum and Nelson, 1997). Moreover, sticky price models with endogenous investment imply unrealistically high volatility in the endogenous variables. In other words, changes in nominal interest rates translate one to one into changes in real rates, therefore leading to excessively high volatility of investment. However, neglecting the endogenous determination of investment eliminates one of the main benefits of the DSGE approach prompted by Kydland and Prescott (1982), namely that it is inherently intertemporal in nature and incorporates the supply side of

⁷For a more complete survey see Boianovsky and Trautwein (2006a) and Mazzocchi et al. (2009).

⁸The same approach is used by Jeanne (1998).

the economy. Indeed, as King and Rebelo argue, "*the process of investment and capital accumulation can be very important for how the economy responds to shock*" (King and Rebelo, 2000, p.6). Thus modeling investment demand might help explain some empirical regularities which would be hard to capture if consumption were the only component of aggregate demand. Last but not least, it should be remembered that the *intertemporal* coordination problem between future consumption (saving) and future production (investment) is the key problem to be solved by the interest rate in general equilibrium theory. Ignoring investment dynamics would leave the sole *intratemporal* coordination problem between current aggregate demand and supply at each date that is dealt with by the spot price system. For these reasons Woodford (2003, p. 352-378; 2004) - but also other authors (Casares and McCallum, 2000; Sveen and Weinke, 2003; 2004) - extend the basic model to include fixed capital and the effects of the related investment dynamic. The purpose of these extensions is not to offer a fully realistic quantitative model of the monetary transmission mechanism, but rather to provide insights regarding several modelling techniques that are used in a number of recent examples of estimated models with optimizing foundations. The model is fully derived and described in Chapter 1.

The strategy of the NNS to minimize the frictions that are required to reproduce real effects of monetary policy and an interaction between interest and prices comes at the price of some ad-hocery and other shortcomings that have been criticized by way of many papers (Boianovsky and Trautwein, 2006b; Trautwein, 2006; Trautwein and Zouache, 2009; Laidler, 2006; Tamborini, 2006; Tamborini, 2010a). Some of the ad-hocery might be refined and made redundant in future version of the NNS, but some of it are indispensable for intertemporal equilibrium modeling of the current kind (Canzoneri et al., 2004; Blanchard and Galí, 2005). Also the ideal continuity of the NNS with the great founders of modern macroeconomics thought - not only Keynes but also Wicksell - was subject to strong criticism. No doubt, there are many points of apparent coincidence between the NNS and the ideas of Wicksell and Keynes. Probably for many readers the idea that Keynes and Wicksell can coexist in a common framework can be confusing or rather troublesome⁹. However, in light of the contribution made

⁹Long standing Keynes' hexegetics highlights the paradigmatic divorce that occurred in his thought between the early Wicksellian inspiration of the *Treatise on Money* and the *General Theory* (see Chick, 1983; Rogers, 1989). There is ample textual evidence (notably Keynes, 1937a, 1937b, 1937c) that in the search of a consistent explanation of fluctuations in *real* income, Keynes divorced from Wicksell not on the grounds of imperfect goods market. He realized that a different theory of the interest rate was needed. The idea of the monetary nature of the interest rate related to liquidity

by the NNS, this interminable theoretical dispute disappears by means of a simple and very popular mechanism: *sticky prices*. In NNS treatment, sticky prices are necessary and sufficient to translate Wicksell's interest-rate theory of the price level into a theory of output and prices fluctuations with apparent Keynesian features. As Woodford outlines "*it is only with sticky prices that one is able to introduce the crucial Wicksellian distinction between the actual and the natural rate of interest, as the discrepancy between the two arises only as a consequence of a failure of prices to adjust sufficiently rapidly*" (Woodford, 2003, p.232). Whereas the NNS concentrates the non-Walrasian features of the economy in the goods (and/or labour) market, the capital market remains perfectly Walrasian granting continuous intertemporal equilibrium. This is the key point in which the NNS theoretical framework differs from old macroeconomics substantially, so much that one wonders whether the points of coincidence may survive to closer inspection (Mazzocchi et al., 2009). Indeed both Keynes and Wicksell assumed that the problem was neither the price of goods nor the wage, but the price of loans, i.e. the interest rate (Leijonhufvud, 1981).

A first departure from the assumption of perfect capital markets is the existence of intermediaries (the banking system) between savers (households) and investors (firms). If the banking system plays an active role, the idea that the equilibrium on the capital market - defined by the forces of productivity and thrift - is found at the full-employment level is no longer valid. All three actors on the capital market act with incomplete and limited information, which is the reason why deviations of the market interest rate from the natural rate may arise. The interference of the banking system with the natural rate can occur because Wicksell's cashless economy is not a moneyless economy (Laidler, 2006, p. 3). Therefore each agent can increase his/her nominal purchasing power either selling goods and services or borrowing money from someone else. As long as non-bank agents borrow and lend one with the other, the total amount of nominal purchasing power in the economy is redistributed but cannot increase. By contrast, a bank is in a position to grant additional nominal purchasing power to anyone with no one else in the economy undergoing an equivalent reduction. Moreover, a bank can increase its own nominal purchasing power by borrowing from the central bank. Thus the problem is that the banking system as a whole might both expand the total nominal purchasing power in the economy and allocate it at terms that differ from those dictated by full-

preference was conceived as the wedge to be driven in the self-equilibrating mechanism of saving and investment without postulating the role of the banking system. Paving the way of the liquidity preference hypothesis, Keynes ultimately negated the possibility of stability (De Antoni, 2009, p. 11).

employment saving-investment equilibrium. The capital market is thus *imperfect* in that the banking system may fail to manage the nominal interest rate consistently with the natural rate. But this is not a question of policy failure, rather a result of the fact that the natural rate is unobservable and neither the financial system nor anybody else has direct information about it¹⁰.

The consequence of the market real interest rate on loans being higher/lower than the natural rate is that households wish to save more/less whereas firms wish to invest less/more: neither side of the market can achieve intertemporal equilibrium of plans. Thus, changes in prices and quantities are the symptom that excess saving or excess investment are being accommodated at the “wrong” market rate and the economy was driven out of the intertemporal equilibrium path. The dynamics of both output and inflation are *disequilibrium phenomenon* and they should necessarily be examined as out-of-equilibrium processes. This interpretation of changes in the price level and production is in sharp contrast with the one put forward in the NNS model, where they are consistent with all markets being cleared and households and firms being in intertemporal equilibrium continuously. Yet ruling saving-investment imbalances out of the theory constitutes a major theoretical weakness (Leijonhufvud, 1981; Van der Ploeg, 2005).

On the policy front, whereas the distortionary effects of sticky prices are the *raison d’être* of monetary policy in the NNS, older mainstreams argued that interest rates should be brought under policy control not because prices do not move enough, but because unfettered interest rates may force prices and quantities to move out-of-equilibrium. On the other hand, changes in the price and output levels are a means to re-equilibrate the economy only if they induce the nominal interest rate to close the gap with the natural rate. For reasons that we cannot consider here, NNS macroeconomics took the easier, perhaps realistic, shortcut of sticky prices at the cost of obscuring one of the most important keys to understanding business cycles, that is their dimension of *intertemporal coordination failures*. Nevertheless other economists maintained the focus on the role of saving-investment imbalances and the underlying capital-market imperfections (Leijonhufvud, 1981; Greenwald and Stiglitz, 1987, 1993; Hahn and Solow, 1995). Despite the methodological differences, common to these views is the idea that

¹⁰Up to date econometric research is by no means encouraging on the possibility that central banks can ever obtain all information necessary to target the natural rate precisely (Amato, 2005; Garnier and Wilhelmsen, 2005; Caresma et al., 2005). A growing literature is now concerned with monetary policy under imperfect information (Orphanides and Williams, 2002b).

the older macroeconomics of saving-investment imbalances does offers guidance for consistent foundations of the interest-rate theory and practice of monetary policy precisely because it focuses on the interest rate as “the wrong price” in the system and lead us to investigate how the monetary authority can manage to “get it right”.

2.3 The Model

2.3.1 Basic Setup

In order to assess and hopefully clarify some basic issues concerning the macroeconomic of saving-investment imbalances, let me introduce the same general equilibrium framework underlying the NNS models, where perfect capital market, monopolistic competition and the sticky price assumptions are replaced by imperfect capital market, perfect competition and flexible prices (Tamborini, 2010b; Mazzocchi et al., 2009). Adding goods market imperfections, sticky prices and wage rigidities may enrich the model for empirical purposes, but, contrary to what is claimed by the NNS, it is not theoretically indispensable.

The economy consists of three competitive markets - for labour, capital and output - and rational forward-looking agents. Households own the inputs and assets of the economy, including ownership rights in firms, and choose the fractions of their income to consume and save. Firms hire inputs and use them to produce goods that they sell to households or to other firms. All exchanges take place in terms of a general unit of account of value $\frac{1}{P_t}$, where P_t is the general price level. For sake of concreteness and comparison with the standard NNS model, I have posited specific functional forms for the production function and the utility function.

I assume that the supply side of the economy is characterized by the following technology:

$$Y_t = K_t^a L_t^{1-a} \tag{2.1}$$

Where Y_t is the flow of output, K_t is the available capital stock and L_t is the labour input. The chosen production function satisfies the traditional neoclassical properties. Moreover, we assume a capital accumulation technology such that the share of output transformed into capital at time t takes one period to become operative (Christiano and Todd, 1996; Kydland and Prescott, 1982)¹¹. These two conditions permit us to

¹¹The accumulation function may take different forms, with (slight) differences in result. Here we have followed the “time-to-build” (Kydland and Prescott, 1982) or “time-to-plan” hypothesis (Chris-

write the transition law of capital stock as:

$$K_{t+1} = I_t + (1 - \delta)K_t \quad (2.2)$$

where I_t is net investment and $I'_t = I_t + (1 - \delta)K_t$ is the gross investment (inclusive of capital replacement). For the sake of simplicity we assume that capital depreciates at a constant rate $\delta = 1$. At each point in time all the capital stock wears out and, hence, can no longer be used for production¹².

As far as capital is concerned, firms can finance gross investment out of households' gross saving by issuing one-period bonds B_t bearing a nominal interest rate i_t . By analogy with physical capital, bonds are indexed by their maturity, i.e. t denotes bonds issued at time $t - 1$ with maturity t . Note, therefore, that the market real interest rate relevant to the saving/investment decisions in period t is given by $R_t = \frac{1+i_{t-1}}{1+\pi_t}$, where π_t is the rate of inflation of the output price P_t , whereas the actual real interest rate that households earn in each t is given by $R_{t+1} = \frac{1+i_t}{1+\pi_{t+1}^e}$, where e denotes an expected value.

In the labour market¹³, firms bargain with workers over a real wage ω_t before production takes place, but labour contracts are in nominal terms W_t . The nominal wage rate is obtained by way of indexation of the negotiated real rate ω_t to the expected price level $P_t^e = P_{t-1}(1 + \pi_t^e)$. Hence the nominal wage rate results

$$W_t = \omega_t P_{t-1} (1 + \pi_t^e)$$

The *contractual* wage is set at the competitive full-employment equilibrium¹⁴. Sub-

tiano and Todd, 1996): the underlying idea reflects the fact that firms often decide to carry out new projects and there is a lag between the decision and its implementation. As argued by Blanchard and Fischer (1989), many capital expenditure decisions take long periods to achieve fruition justifying the assumption of a planning before actual investment expenditure is implemented.

¹²This shortcut avoids another problem: if the model allows for fixed capital - instead of only circulating capital - it runs up against the problem on how to evaluate existing capital stock *off* the intertemporal general equilibrium path. The solution of this trouble would require the integration of short-run and long-run macroeconomics and consequently the description of the term structure of interest rates. Yet, this task is beyond the scope of this paper. I owe this point to Robert Solow.

¹³This representation of the labour market is akin to Keynes (1936, ch. 19). See also Hargreaves-Heap (1992).

¹⁴This is only a simplifying assumption. Whether the equilibrium employment is equal to, or less than, the total labour force is immaterial here, or as implicit as the labour market in Woodford's version of the NNS. Another characterization of labour market equilibrium may be obtained by way of "real rigidities" like efficiency wages. With this assumption it would seem natural to think that at the intertemporal general equilibrium, real wage rate still has some unutilized resources.

sequently, firms choose L_t for production, observing the actual wage rate w_t given by the nominal rate deflated by the *actual* price level P_t , namely $w_t \equiv \frac{W_t}{P_t}$. Since $P_t = P_{t-1}(1 + \pi_t)$,

$$w_t \equiv \omega_t \frac{1 + \pi_t^e}{1 + \pi_t}$$

For each period t , firms' programmes consist of the choice of labour input L_t^* for current production and the capital stock K_{t+1}^* for the next one, in order to maximize their expected profit stream, given (2.1), (2.2) and the gross income distribution constraint, namely:

$$\max_{L_t; K_{t+1}} E_t \left[\sum_{s=0}^{\infty} \Theta^{-s} (Y_{t+s} - w_{t+s} L_{t+s} - R_{t+s} K_{t+s+1}) \right] \quad (2.3)$$

The FOCs for firms are thus the following:

$$K_{t+1}^* = L_t^* \left(\frac{a}{R_{t+1}} \right)^{\frac{1}{1-a}} \quad (2.4)$$

$$L_t^* = K_t \left(\frac{1-a}{w_t} \right)^{\frac{1}{a}} \quad (2.5)$$

where w_t is the real wage rate, and R_t is the real gross return to be paid on the capital stock operative at time t and purchased at time $t - 1$.

The households hold claims to the capital stock of the economy, supply their whole labour force L_t inelastically, and choose a consumption plan $\{C_{t+s}\}_{s=0}^{\infty}$ in order to maximize their utility under the following budget constraint:

$$C_t + S_t = Y_t \quad (2.6)$$

where S_t is net saving. In consideration of the assumptions concerning the capital accumulation technology, and of the definition of Y_t , the households' budget constraint (2.6) can also be written as:

$$B_{t+1} = H_t + R_t B_t - C_t \quad (2.7)$$

where $H_t = w_t L_t$ is labour income and B_t is the outstanding real stock of bonds¹⁵. Consequently $B_{t+1} - B_t = S_t$ is the net saving, thus if $S_t > B_t$, then $B_{t+1} > B_t$.

¹⁵By analogy with physical capital, bonds are indexed by their maturity, i.e. B_t are bonds purchased in $t - 1$ with maturity in t , etc.

Therefore, given a constant rate of time preference $\theta > 0$ and $\Theta \equiv 1 + \theta$ the households' intertemporal maximization problem is¹⁶:

$$\max_{C_t} E_t \left[\sum_{s=0}^{\infty} \Theta^{-s} U(C_{t+s}) \right] \quad (2.8)$$

subject to the iterated budget constraint (2.7):

$$C_t + \sum_{s=1}^{\infty} E_t \frac{C_{t+s}}{\prod_{s=1}^{\infty} R_{t+s}} + \frac{B_{t+s+1}}{\prod_{s=1}^{\infty} R_{t+s}} = H_t + \sum_{s=1}^{\infty} E_t \frac{H_{t+s}}{\prod_{s=1}^{\infty} R_{t+s}} + R_t B_t$$

where the transversality condition imposes:

$$\lim_{s \rightarrow \infty} \frac{B_{t+s+1}}{\prod_{s=1}^{\infty} R_{t+s}} = 0$$

The households' FOC, as of time t , is thus characterized by:

$$U'(C_t) = E_t \left[\frac{U'(C_{t+1})}{\Theta} R_{t+1} \right]$$

Preferences of the households are described by the following logarithmic utility function¹⁷:

$$U(C_t) = \ln C_t$$

therefore the household's optimal consumption is:

$$C_t = E_t \left[\frac{C_{t+1}}{R_{t+1}} \Theta \right] \quad (2.9)$$

In order to isolate the macroeconomic effects of the interest-rate gaps, the analysis should start at a point in which the economy is in intertemporal general equilibrium. Therefore we can consider the (stationary) steady-state solution SS for firms' and households' optimal plans (2.4), (2.5), (2.9), given full employment normalized to one, $L^{SS} = 1$ and $\pi_{t+1}^e = \pi_t^e = \pi_t = \pi^{SS} \geq 0$. Hence the return to capital will be $R_{t+1} = \Theta = R^{SS}$, so that for all t , $C_{t+1} = C_t = C^{SS}$. For the given production function

¹⁶where $U'(C_t) > 0, U''(C_t) < 0$.

¹⁷This functional form has the advantages that the optimal consumption does not depend on the time horizon of the model.

(2.1), the constant real interest rate also yields a constant capital stock K^{SS} and hence constant output and factor incomes, that is $F'_K = R^{SS}$, $B_t = K_{t+1} = K^{SS}$, $Y_t = Y^{SS} = H^{SS} + R^{SS}K^{SS}$. As long as optimal saving is equal to optimal investment, the real value of bonds with maturity at any time t coincide with the operating capital stock, $B_t = K^{SS}$. Consequently, the resource constraint is satisfied for:

$$C^{SS} \left(1 + \sum_{i=1}^{\infty} \frac{1}{R^{SSi}} \right) = H^{SS} \left(1 + \sum_{i=1}^{\infty} \frac{1}{R^{SSi}} \right) + R^{SS}K^{SS}$$

Since $\lim_{i \rightarrow \infty} \sum_{i=1}^{\infty} \frac{1}{R^{SSi}} = \frac{1}{r^{SS}}$, we could obtain the optimal consumption, the optimal capital stock and the equilibrium output as follows:

$$C^{SS} + K^{SS} = Y^{SS} \quad (2.10)$$

$$K^{SS} = \left(\frac{a}{R^{SS}} \right)^{\frac{1}{1-a}} \quad (2.11)$$

$$Y^{SS} = K^{SSa} \quad (2.12)$$

The real interest rate R^{SS} associated with the intertemporal general equilibrium is the so called *natural rate of interest*. This implies that $S'_t = I_t + K_t = I'_t = K^{SS}$, that is, in steady-state net saving and investment are nil in all t , and the economy only replaces the optimal stock of capital K^{SS} . Finally, it should be $(1 + i_t) = R^{SS}(1 + \pi_{t+1}^e)$ for all t . Note that the system has thus three key elements: first, the rate of time preferences of households¹⁸, $\Theta = R^{SS}$; second, the market real rate of interest, R_{t+1} ; third, the return to capital, R_{t+1}^* . In order to achieve the steady state we should have that $\Theta = R_{t+1} = R_{t+1}^* = R^{SS}$. Intuitively a variation of R_{t+1} will influence (with some delay due to time lag or adjustment costs of capital) R_{t+1}^* , so we can assume that on average $R_{t+1} = R_{t+1}^*$. But as long as $R_{t+1} \neq \Theta = R^{SS}$ a gap remains. This point will be clearer in the subsequent sections.

¹⁸Abstracting from technical progress or technology shocks, this is a Sidrausky-type steady-state, where the key variable in the capital market is the rate of intertemporal consumer preferences Θ .

2.3.2 Three-Gaps analysis

Let me suppose that, during any period t , the economy may be hit by a shock to the capital market. The shock may be *real* (a change in the determinants of thrift or productivity not matched by i_t) and imply a new natural interest rate, or it may be *nominal* (a disturbance to the nominal interest rate, i.e. i_t is set or changed inconsistently with the natural rate) and generate a divergence between the market real rate R_{t+1} and the existing natural rate R^{SS} . As will be seen, the only key variable in the problem at hand is the gap between the market and the natural rate, while which of the two has been shocked is immaterial here.

Before proceeding, it should be borne in mind that the problem is neither one of trades at the “right” rate, nor is it one of quantity rationing at a fixed rate (Hargreaves-Heap, 1992), but it is one of market-clearing trades at the “wrong” rate allowed for by bank intermediation. It is not a semantic distinction: in the case of rationing the market does not clear and, generally, the “short-side of the market” rule is invoked¹⁹. In the latter case, the market may well clear, but the distinction between *notional* plans and *actual* trades is introduced. Notional plans are those that agents would realize if they could trade at the general equilibrium prices. Conversely, actual trades are those that agents realize upon observing spot market prices. Thus actual trades may differ from notional plans if one or more spot prices observed in one or more markets are not general equilibrium prices.

This scheme is appropriate to the role of the central bank as it pegs the nominal interest i_t under limited information. Pegging implies that as long as $R_{t+1} \neq R^{SS}$ an excess investment (supply of bonds) or saving (demand for bonds) in the capital market arises. The central bank’s open-market operations that peg the nominal interest rate entail that the excesses of supply or demand of bonds are cleared by way of purchases or sales by the central bank. These allow excess investment/saving to be financed and allow households and firms to carry on their saving and investment *actual* plans, respectively. However, these are not the *notional* plans that would be undertaken with $R_{t+1} = R^{SS}$, and the inconsistency between the actual households’ consumption plans and firms’ capital-stock choices will spill over across markets and time. In other words, the following proposition hold:

Proposition 1 *Given $R_{t+1} \neq R^{SS}$ in any period t , although the bonds market clears, the*

¹⁹For example, if $R_{t+1} > R^{SS}$ firms realize their planned investment whereas households are constrained to save less than planned.

Bond Market (at time t)	$R_{t+1} > R^{SS}$	$R_{t+1} < R^{SS}$
Output Market (at time t)	Excess Supply	Excess Demand
Output Market (at time t+1)	Excess Demand	Excess Supply

Table 2.1 – Disequilibrium relations

ensuing levels of saving and investment are not consistent with the intertemporal general equilibrium values of output and at the general price level that would obtain at the natural rate of interest R^{SS} both in t and in the subsequent periods.

The proof of this proposition is a well-known implication of Walras Law. Actual consumption is given by (2.9) whereas actual investment of firms is given by (2.4). Ceteris paribus, with respect to the intertemporal general equilibrium, $R_{t+1} \neq R^{SS}$ consumption to the present ($R_{t+1} < R^{SS}$) or to the future ($R_{t+1} > R^{SS}$), while investment in t - and the capital stock available in $t + 1$ - are increased/reduced respectively. Consequently, there is a unique relationship between interest-rate gaps and saving-investment gaps, namely if $R_{t+1} > R^{SS}$ then $S'_t > I'_t$ and if $R_{t+1} < R^{SS}$ then $S'_t < I'_t$.

In Table 2.1 I briefly recall the disequilibrium relations in the goods market associated with $R_{t+1} \neq R^{SS}$ in the bond market. Now let us consider the case $R_{t+1} < R^{SS}$. In this case, the central bank clears the excess supply of bonds so that firms are allowed to invest more (by adding physical capital to their net worth) than households are actually ready to save (adding more bonds to their wealth). The consequence of this discrepancy is an excess demand in period t and an excess supply in period $t + 1$, corresponding to a production capacity that is not matched by planned consumption. If we abide by the principle that *markets always clear*, we should understand how these *intratemporal* and *intertemporal* inconsistencies among notional plans can be brought into equilibrium. To this effect, I put forward the following proposition:

Proposition 2 *Given $R_{t+1} \neq R^{SS}$ in any period t , there exists one single sequence of output and price realizations in t and onwards that clears the output market. By implication of Proposition 1, these realizations cannot be the same that would obtain with $R_{t+1} = R^{SS}$.*

The full proof is provided in Appendix. The intuition of the proof is as follows: given $R_{t+1} \neq R^{SS}$, what is the sequence of real income realizations that would “force” the

households' consumption plan to be consistent with the capital path chosen by firms? The solution technique, drawn from Smith and Wickens (2006) and Tamborini (2010b), consists of plugging each period budget constraint (2.7) into households Euler equation (2.9). Note that as long as $R_{t+1} \neq R^{SS}$, then $B_{t+s} \neq K_{t+s}$, $s = 1, \dots, \infty$, that is, the value of real bonds over time is inconsistent with that of real capital. Hence, to correct for this “wrong accounting” of real resources, the “forcing constraint” $B_{t+s} = K_{t+s}$, $s = 1, \dots, \infty$, should also be added to the planning problem. As is proved in Appendix, the answer to the above question is the following:

$$Y_t = E_t Y_{t+1} \frac{R^{SS}}{R_{t+1}} + K_{t+1} \left(1 - \frac{R^{SS}}{R_{t+1}} \right) \quad (2.13)$$

Then, in order to gauge the rate of deviation from the intertemporal general equilibrium output path, both sides are divided by Y^{SS} . Denoting $\hat{Y}_t \equiv \frac{Y_t}{Y^{SS}}$, $\hat{R}_t \equiv \frac{R_{t+1}}{R^{SS}}$ the output and interest-rate gaps, respectively, the following sequence of output gaps is obtained

$$\hat{Y}_{t+1} = \hat{R}_t^{-\frac{a}{1-a}} \quad (2.14)$$

$$\hat{Y}_t \approx \hat{R}_t^{-\frac{1}{1-a}} \quad (2.15)$$

As explained above, these output gaps are necessary to force the consumption path of households to be consistent with the capital path chosen by firms, given $R_{t+1} \neq R^{SS}$ and output market clearing at all dates.

To understand the reasons underlying these results, consider again the case in which $R_{t+1} < R^{SS}$ or $\hat{R}_t < 1$. As we have seen, households in period t reckon a real value of bonds that is smaller than the real value of capital that bonds are supposed to represent. Hence, the economy needs a *real* correction of resource accounting: to this effect, output (real incomes accruing to households) should be greater along the whole consumption path of households, namely $\hat{Y}_{t+s} > 0$ (with $s = 0, \dots, \infty$).

Parallely, in Appendix I show that in order for profit-maximizing firms to increase output with respect to potential, the inflation rate, too, should be (unexpectedly) different than the normal rate embedded in nominal wage contracts according to

$$\tilde{\Pi}_t = \left(\frac{\hat{Y}_t}{\hat{K}_t} \right)^{\frac{a}{1-a}} \quad (2.16)$$

where $\tilde{\Pi}_{t+1} \equiv \frac{1+\pi_t^c}{1-\pi_t}$ and $\hat{K}_t = \frac{K_t}{K^{SS}}$. Recall that the *contractual* nominal wage rate

in force in each period is set ex-ante according to $W_t = \omega_t P_{t-1} (1 + \pi_t^e)$, where ω is the full-employment real wage. In order to produce $Y_t \neq Y^{SS}$, firms should face an *actual* real wage, $w_t = \omega_t \frac{1+\pi_t^e}{1+\pi_t}$, realigned with the ensuing marginal product of labour. For instance, in order to produce more, firms should either face a positive “inflation surprise” that lowers the actual real wage or have greater capital or both.

To sum up, I have shown that in the presence of an interest-rate gap, and the underlying investment-saving imbalance, goods and labour market-clearing over time can only take place by way of a sequence of output gaps and inflation surprises with respect to their intertemporal general equilibrium values. Analyzing expressions (2.14)-(2.15) and (2.16) in more detail, they present two main features that distinguish them from the standard NNS model and that result directly from the underlying out-of-equilibrium nature of the model. The first concerns output gaps. Notably, this result is reminiscent of Keynes’s claim that investment-saving imbalances are corrected through changes in real incomes. As can be seen, however, the main implication is a sequence of intertemporal and interconnected output gaps each depending on the current interest-rate gap. This may be called a “feed-forward effect” of interest-rate gaps and it is related to the fact that I have retained the assumption that agents are forward-looking. By contrast, in the NNS framework each period’s output gap only depends on the contemporaneous interest rate gap²⁰, so that the feed-forward effect is absent.

The second feature to be noted concerns inflation gaps. The price level changes as much as is necessary to equate demand and supply, given the expected inflation rate. Hence, price stickiness is not an issue²¹. This result is instead reminiscent of Wicksell’s claim that investment-saving imbalances give rise to inflationary phenomena. In this framework they reflect unexpected inflation, whereas in the NNS model they reflect *anticipated* inflation by price-setting firms. What is crucial is that *unexpected* inflation is an integral part of the process in the present model, in the sense that, as long as there exist interest-rate gaps - and hence output gaps - the economy must be *off* whatever price level path was expected by agents. As a matter of logic of the rational-expectations hypothesis, inflation expectations can, at best, be elaborated by agents consistently with their notional plans (i.e. the inflation rate that would result if the plans based on saving and investment were in fact the intertemporal general equilibrium

²⁰More precisely, any output gap at time t depends on the expected output gap and the present interest rate gap which, ultimately, depends on the future interest rate gaps.

²¹Of course, different microeconomic assumptions may lead to different results and different combinations of price-quantity changes, but this is an empirical matter.

plans) but these turn out to be unfeasible in the output market. Hence also the related expectation of the inflation rate will be falsified.

2.3.3 A log-linear version

To set the stage for further analyses and facilitate comparison with the NNS framework, I present now a log-linear version of the previous model. As usual log-variables are denoted with small-case letter of the corresponding symbol. Let me first analyze the output gaps (2.14)-(2.15). The main implication of an interest rate gap is a sequence of intertemporal output gaps, each depending on the current interest rate gap. In the Appendix I show that, since \hat{Y}_t and \hat{Y}_{t+1} share the same common factor, $\frac{R^{SS}}{R_{t+1}}$, it is in general possible to express them in a single reduced form displaying (spurious) autocorrelation. Hence a new “Investment and Saving” IS function is obtained:

$$\hat{y}_{t+1} = \rho \hat{y}_t - \alpha \hat{i}_t \quad (2.17)$$

where $\hat{y}_t \equiv \ln \hat{Y}_t$, $\hat{i}_t = i_t - \pi_{t+1}^e - r^{SS}$ and where ρ and α are two parameters such that:

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

There is a clear analogy with the IS in the NNS model. Yet there are also substantial differences. As a consequence of the intertemporal “feed-forward effect” of interest-rate gaps, which is not in the NNS model, this generate time series of output gaps that, *ex-post*, display two main features: first, a dependence on the lagged values of interest-rate gaps, and second, some degree of spurious serial correlation or “inertia” between \hat{y}_{t+1} and \hat{y}_t measured by the parameter ρ . Notably, a dynamic structure like (2.17) is consistent with recurrent empirical estimates of IS equations (Laubach and Williams, 2003; Caresma et al., 2005; Orphanides and Williams, 2002a; 2006). These empirical regularities are not easily accommodated in the NNS framework unless it is filled with additional *ad hoc* frictions, usually interpreted as the outcome of backward-looking behaviour of agents (Aghion et al., 2004; Mankiw and Reis, 2003; Sims, 2003). Here the correlations result directly from forward-looking agents and the fact that intertemporal disequilibrium connect each period’s variables in a way that is not captured by the NNS framework²². In the present model, the usual findings that $0 < \rho < 1$ and $\alpha > 0$, imply

²²This specification entails considerable differences in the dynamic properties of the economy (see Chapter 3).

that $\rho < a$.

Let me now turn to the inflation rate consistent with \hat{y}_{t+1} . This can be obtained from the inflation equation (2.16) for $t + 1$, which is in fact a ‘‘Aggregate Supply’’ equation (AS). As shown in Appendix, it can easily be log-linearized as follows:

$$\pi_{t+1} = \pi_{t+1}^e + \kappa \hat{y}_{t+1} + v \hat{i}_t \quad (2.18)$$

where:

$$\kappa = \frac{a}{1-a} \quad v = \frac{a}{(1-a)^2}$$

Parameter κ represents the inflation/output elasticity while v could be interpreted as the elasticity of the capital stock to the interest-rate gap. Again we can make a comparison between our AS equation and the so-called New-Keynesian Phillips Curve in the standard NNS model. Our AS indicates that the future inflation rate in $t + 1$ will depend on its expectation as of t , on the future output gap, and on the current interest-rate gap. First of all, as explained above, as long as a non-zero interest-rate gap persists, an inflation surprise, $\pi_{t+1} \neq \pi_{t+1}^e$, will arise. In the second place, also the adjustment dynamics of the capital stock induced by the interest-rate gap is crucial, a factor which is ignored by the NNS²³. As indicated by the parameter $v > 0$, with $\hat{i}_t \neq 0$ there is positive/negative net investment and the capital stock will be above/below its steady state level thereby modifying the productive capacity of the economy. This means that an interest-rate gap affects not only aggregate demand, but also aggregate supply. This phenomenon is often referred to as saying that aggregate supply and demand ‘‘moves together’’ (Greenwald and Stiglitz, 1987). For instance, a negative interest-rate gap generates excess aggregate demand, but it will also spur productive capacity exerting a countervailing pressure on future inflation. The final outcome will depend of the relative movement of the two curves. As we shall see, this feature will significantly change the policy conclusions that can be drawn from the model.

²³Of course, if the interest rate gap is zero, the capital stock is $K_{t+1} = K^{SS}$ and thus we have zero net investment (only capital stock replacement). This conclusion holds only in a stationary steady-state analysis. Indeed, if we introduce a positive rate of growth of population (and possibly a technological progress), we should observe a positive net investment to keep constant the per-capita capital stock even if $R_{t+1} = R^{SS}$.

2.3.4 A model check

It is now convenient to re-express the AS equation in terms of the inflation surprise $\tilde{\pi}_{t+1} = \pi_{t+1} - \pi_{t+1}^e$, that is:

$$\tilde{\pi}_{t+1} = \kappa \hat{y}_{t+1} + v \hat{i}_t \quad (2.19)$$

Consequently, the IS-AS equations form a first-order difference, non-homogeneous system in the two gaps $[\hat{y}_{t+1}; \tilde{\pi}_{t+1}]$ with a given exogenous interest-rate gap $\hat{i}_t \neq 0$. This formulation is sufficient for a preliminary check of its dynamic properties. We have thus a non-homogeneous system:

$$\begin{bmatrix} \hat{y}_{t+1} \\ \tilde{\pi}_{t+1} \end{bmatrix} = \begin{bmatrix} \rho & 0 \\ \kappa\rho & 0 \end{bmatrix} \begin{bmatrix} \hat{y}_t \\ \tilde{\pi}_t \end{bmatrix} + \begin{bmatrix} -\alpha \\ v - \kappa\alpha \end{bmatrix} \hat{i}_t$$

For any initial value $\hat{i}_t = i_0 \neq 0$, it possesses the following steady-state solutions:

$$\hat{y} = - \left(\frac{\alpha}{1 - \rho} \right) \hat{i}_0 \quad (2.20)$$

$$\tilde{\pi} = \left[v - \frac{\kappa\alpha}{1 - \rho} \right] \hat{i}_0 \quad (2.21)$$

That is to say:

Proposition 3 *A permanent interest-rate gap determines permanent output and inflation gaps. Conversely, the output and inflation gaps are nil only if the interest-rate gap is also nil.*

Proposition 4 *If $\rho \in [0, 1[$ output and inflation converge to - and remain locked in - the steady-state values, with both output and inflation being inefficiently high or low, and being inconsistent with their intertemporal general equilibrium expected values.*

These propositions capture the essence of a cumulative processes as disequilibrium phenomena both on the nominal and real side of the economy (Leijonhufvud, 1981, p.136). If $i_0 \neq 0$ and if the initial inflation rate is nil, then the price level is set on the path given by (2.21) where it grows/declines indefinitely at a constant rate²⁴. As

²⁴Cumulative processes of the price level in the Wicksellian literature are often associated with accelerating inflation rates. This possibility, however, is closely related by Wicksell to the mechanism of expectations formation: *as long as the change in prices (...) is believed to be temporary, it will in fact remain permanent*" (Wicksell, 1922, XII, n.1).

long as the interest-rate gap is not closed, changes in the price level persist. This fact raises the problem of how expectations are possibly revised, and how the revision mechanism impinges upon the dynamic process. This problem will be reconsidered in section [2.3.5]. Instead, the real disequilibrium shows that 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. Indeed a *real* misallocation requires a *real* resource adjustment, irrespective of the degree of flexibility of prices²⁵.

Let me say a few words on the sign of the two gaps. Equation (2.20) and (2.21) can be rewritten as:

$$\hat{y} = \frac{a - \rho}{(a - 1)(1 - \rho)} \hat{i}_0 \quad (2.22)$$

$$\tilde{\pi} = \frac{a}{(a - 1)(\rho - 1)} \hat{i}_0 \quad (2.23)$$

The coefficient of \hat{i}_0 in the first equation is negative as long as $a > \rho$ whereas it is always positive in the second equation. Therefore given the structural values of the parameters, if $\hat{i}_0 < 0$ we will have a positive output gap ($\hat{y} > 0$) and a negative inflation gap ($\tilde{\pi} < 0$). This last result seems to run contrary to the standard macroeconomics models used nowadays²⁶. It depends neither on the structural construction of the model nor on its microfoundation, rather it is due to the choice of the Cobb-Douglas production function and the underlying hypothesis of constant returns to scale. This assumption determines an excessive elasticity of the capital stock to the interest rate, measured by the parameter ν , which amplifies the adjustment of the aggregate supply²⁷. Intuitively, if $\hat{i}_0 < 0$, we have a big increase of the the capital stock and the AS curve will move much more than the AD. Hence, the dynamics will conclude with a negative inflation gap. Conversely, if the reactivity of the capital stock to the interest rate is low (as the empirical evidence seems to suggest), the AS will move slightly and the system will end with a positive 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.

²⁵This aspect was underscored, but not denied, by Wicksell whereas it was brought into full light by Keynes with his theory of effective demand. Nevertheless, contrary to interpretations of the Old and New Synthesis, Keynes did not ignore that (unexpected) deflation (2.21) was the counterpart to the real adjustment process of supply and demand (Keynes, 1936, ch.19).

²⁶In any case we should note that a negative inflation gap is present also in Casares and McCallum (2000) and Ellison and Scott (2000).

²⁷It is simple to prove that with increasing return to scale, $a + b > 1$, the elasticity of the capital stock to the interest rate gap would be less. Same thing if a is small enough.

These results seem to correspond to a stage described by Keynes when he emphasized that aggregate demand and aggregate supply could contract/expand in a multiplier process at an (nearly) unchanged price level. This conclusion significantly alters certain policy provisions provided by the NNS (see Chapter 3).

2.3.5 Extensions

Adjustment costs of capital

So far we have assumed that the capital stock is always equal to the one obtained from the FOCs, namely $K_{t+1} = K_{t+1}^*$. This does not represent a problem in standard RBC models because technology shocks have a large impact on the real interest rate, consequently the response of investment mimics its empirical counterpart well. However this assumption presents some theoretical and empirical problems in sticky prices model of NNS framework. Indeed, as Ellison and Scott (2000) pointed out, models with endogenous capital stock imply unrealistically high volatility of investment. This depends on the fact that changes in the nominal interest rate translate *one-to-one* into changes in the real rates leading to the excessively high volatility of all endogenous variables. This problem also arises in the basic framework I presented in the previous sections: it is sufficient to look at equation (2.4) to note that a change in market interest rate is fully translated on investment and thus on the capital stock of the next period, causing large and immediate adjustments. The usual shortcut to have more realistic movements of capital and investment is to posit some form of adjustment costs which are able to "buffer" the capital stock adjustment. An example of such costs are those of installing new capital and training workers to operate new machines (Eisner and Strotz, 1963; Lucas, 1967)²⁸. We follow the same path. Let me suppose that in each period firms face the following adjustment-cost function:

$$Z_t = \mu_1(K_{t+1} - K_{t+1}^*)^2 + \mu_2(K_{t+1} - K_t)^2 \quad (2.24)$$

We could interpret μ_1 as unitary *disequilibrium costs*, i.e. the cost to have a capital stock different from the optimal one (given the interest rate). Vice-versa, we could interpret

²⁸Usually the key assumption of the NNS model with endogenous investment is that firms face costs of adjustment which are a convex function of the rate of change of their capital stock (Casares and McCallum, 2000; Woodford, 2003)²⁹. These assumption implies that it is costly for a firm to increase or decrease its capital stock and that the marginal adjustment cost is increasing in the size of the adjustment.

μ_2 as the unitary *change costs* of the capital stock from one period to another. Given K_{t+1}^* and K_t , the firm seeks to minimize Z_t as follows:

$$\min_{K_{t+1}} Z_t = E_t \left\{ \sum_{s=0}^{\infty} \left[\mu_1 (K_{t+s+1} - K_{t+s+1}^*)^2 + \mu_2 (K_{t+s+1} - K_{t+s})^2 \right] \right\} \quad (2.25)$$

and thus:

$$K_{t+1} = (1 - \psi)K_{t+1}^* + \psi K_t \quad (2.26)$$

where $\psi = \frac{\mu_2}{\mu_1 + \mu_2}$. Let me briefly discuss the two limit cases. First, if the disequilibrium costs are equal to zero we have that $K_{t+1} = K_t$, i.e. the capital stock does not change over time and remains anchored to the steady-state level K^{SS} (Mazzocchi et al., 2009). Second, if the change costs are equal to zero we have that $K_{t+1} = K_{t+1}^*$, i.e. the *actual* capital stock is always equal to the optimal one, given the interest rate. In this way it is as if there were no adjustment costs of capital. This last case bring us back to the basic framework I developed in section [2.3.1].

Let me indicate with $\hat{k}_{t+1} = \log \frac{K_{t+1}}{K^{SS}}$, $K_{t+1} = K^{SS}(1 + \hat{k}_{t+1})$, $K_{t+1}^* = K^{SS}(1 + \hat{k}_{t+1}^*)$ and $K_t = K^{SS}(1 + \hat{k}_t)$. Log-linearizing around the steady-state (Uhlig, 1999) we get:

$$K^{SS}(1 + \hat{k}_{t+1}) = (1 - \psi)K^{SS}(1 + \hat{k}_{t+1}^*) + \psi K^{SS}(1 + \hat{k}_t) \quad (2.27)$$

dividing both sides for K^{SS} and iterating the terms over time we get:

$$\hat{k}_{t+1} = (1 - \psi)\hat{k}_{t+1}^* + \sum_{j=1}^{\infty} (1 - \psi)\psi^j \hat{k}_{t+1-j}^*$$

Since $\hat{k}_t^* = \hat{k}_{t-1}^* = \dots = \hat{k}_{t+1-j}^*$ (with $j = 1, \dots, \infty$) are predetermined variables we get:

$$\hat{k}_{t+1} = (1 - \psi)\hat{k}_{t+1}^* + \sum_{j=1}^{\infty} (1 - \psi)\psi^j \hat{k}_t^*$$

For $0 \leq \psi \leq 1$ we have that:

$$\hat{k}_{t+1} = (1 - \psi)\hat{k}_{t+1}^* + \psi \hat{k}_t^* \quad (2.28)$$

In the Appendix I show that, introducing adjustment cost of capital, the model

(2.17)-(2.19) becomes the following:

$$\hat{y}_{t+1} = \rho \hat{y}_t - \alpha i_t - \beta i_{t-1} \quad (2.29)$$

$$\tilde{\pi}_{t+1} = \kappa \hat{y}_{t+1} + \theta i_t + \sigma i_{t-1} \quad (2.30)$$

where:

$$\alpha = \frac{\rho - a[1 + \psi(\rho - 1)]}{a - 1} \quad \beta = \frac{a\psi(\rho - 1)}{a - 1}$$

$$\kappa = \frac{a}{1 - a} \quad \theta = \frac{a(1 - \psi)}{(1 - a)^2} \quad \sigma = \frac{a\psi}{(1 - a)^2}$$

Not surprisingly it can be seen that, for any initial value $\hat{i}_t \neq 0$ the system possesses the same steady-state as (2.22)-(2.23). In fact, the effect of adjustment costs tend to disappear over time and the capital stock gap will lead to its optimum level \hat{k}_{t+1}^* compatible with the interest rate gap \hat{i}_0 . Nevertheless, adjustment costs have an effect on the convergence dynamics to steady state. If adjustment costs are small, the transient dynamics from a steady state to another is very rapid. Conversely, if the adjustment costs are large enough, the adjustment process may take several periods. All this may have very interesting implications: in fact, a permanent interest rate gap $\hat{i}_0 < 0$ may generate a more or less prolonged inflation phase followed by an outright deflation. I will address this issue again in the next sections.

Inflation expectations

What remains to be determined are the price level and the steady-state inflation rate. As is well-known, a competitive general equilibrium model like the present one leaves the price level and its changes undetermined. A consistent interest-rate theory of the general price level should describe how the nominal interest rate and the inflation expectations are determined, and the interaction between these two variables³⁰. The simplest hypothesis³¹ is to assume a simplified monetary system that consists of a central bank, representing the banking system as a whole. It operates by setting at the beginning of each period t an official inflation target π^* and exerting control on the nominal interest

³⁰Another possible solution is to insert a monetary equation that pins down the price level corresponding to the general-equilibrium output level (Balfoussia et al., 2011).

³¹For alternative hypotheses, such as rational expectations and interest-rate rules, see Mazzocchi (2012).

rate i_t by trading bonds in the open market³². The value at which the central bank set the inflation target is immaterial here. In perfect competition its value should be zero, while with different market structures - for example, imperfect competition - or in presence of real rigidities it should be derived from a welfare computation and it is usually greater than zero. Once the central bank has set π^* , it is ready to create or retire money (the counterpart of bonds) to the extent that is necessary to clear the market. Households and firms make up their expectations according to the announced inflation $\pi_{t+1}^e = \pi^*$ ³³. Then transactions take place and output and inflation for the period are realized.

The problem with this assumption is that, in the event of a persistent interest-rate gap $\hat{i}_t \neq 0$, the future path of the price level will no longer be the same as in the past. In modern parlance, in the course of the cumulative process, expectations of return to normality are systematically falsified. Whereas modern macroeconomists tend to rule this problem out of analysis by focusing exclusively on states of the economy where expectations are statistically correct³⁴ - the so-called *short-run rational expectations* - older mainstreams (see Lindahl, 1939; Lundberg, 1930; Myrdal, 1927) were not concerned with jumps from one equilibrium to the next, and they introduced the hypothesis of learning in the cumulative process that shifts expectations from static to adaptive to forward-looking and eventually rational in the sense of self-fulfilling. The full exploration of such adaptive expectations dynamics is beyond the scope of this paper. Nevertheless there is a literature about heterogenous beliefs in financial market that provides routes to endogenize expectations in terms of rational reactions to the relative success of different strategies (Brock and Hommes, 1997; 1998). Without going too far with the analysis, it may be interesting to examine the case in which the switching of strategies would depend on the costs of sustaining the long-run rational expectations π^* 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 Δ_1 of having an

³²In reality, central banks generally control short-term interest rates only, whereas investment is largely financed with long-term bonds. For an analysis of the transmission of monetary policy through the term structure of interest rates see Turner (2011).

³³This is a difference with respect to the traditional NNS model, in which we observed an “un-anchored” one-period expected inflation $\pi_{t+1}^e = E_t\pi_{t+1}$. It can be shown that this difference does not entail major theoretical implications. This assumption (Tamborini, 2006) is both convenient and consistent with the usual treatment of policy games where the central bank moves first, and the problem is the conditions such that the target is also the rational expectation of the inflation rate, regardless of transitory inflation rates (Evans and Honkapohja, 2001).

³⁴More precisely $E_t(\pi_{t+1} - \pi_{t+1}^e) = 0$ and thus $\pi_{t+1}^e = E_t\pi_{t+1} = \pi_{t+1}$.

inflation expectation other than $E_t\pi_{t+1}$, while the second can be interpreted as the cost Δ_2 of hot adjusting expectation with respect to long-term one π^* . Therefore in each period t agents faces the following cost function:

$$M_t = \Delta_1(\pi_{t+1}^e - E_t\pi_{t+1})^2 + \Delta_2(\pi_{t+1}^e - \pi^*)^2 \quad (2.31)$$

Minimizing with respect to π_{t+1}^e and setting $\xi = \frac{\Delta_1}{\Delta_1 + \Delta_2}$ we get:

$$\pi_{t+1}^e = \xi E_t\pi_{t+1} + (1 - \xi)\pi^* \quad (2.32)$$

To this effect, I replace this last relation in equations (2.19) and (2.17). As a result (see the proof in Appendix):

$$\hat{y}_{t+1} = \rho'\hat{y}_t - \alpha'\hat{i}_t - \beta'\hat{i}_{t-1} \quad (2.33)$$

$$\hat{\pi}_{t+1} = \kappa'\hat{y}_{t+1} + \theta'\hat{i}_t + \sigma'\hat{i}_{t-1} \quad (2.34)$$

where $\hat{\pi}_{t+1} = \pi_{t+1} - \pi^*$ and where:

$$\begin{aligned} \alpha' &= \alpha \frac{1 - \xi}{1 - \xi(1 + \alpha\kappa - \theta)} & \rho' &= \rho \frac{1 - \xi(1 - \theta)}{1 - \xi(1 + \alpha\kappa - \theta)} \\ \beta' &= \frac{\beta[1 - \xi(1 - \theta)] - \alpha\xi\sigma}{1 - \xi(1 + \alpha\kappa - \theta)} & \kappa' &= \frac{\kappa}{1 - \xi(1 - \theta)} \\ \theta' &= \frac{\theta}{1 - \xi(1 - \theta)} & \sigma' &= \frac{\sigma}{1 - \xi(1 - \theta)} \end{aligned}$$

The steady-state solution for $[\hat{y}_{t+1}, \hat{\pi}_{t+1}]$ can simply be restated as follows

$$\hat{y} = - \left(\frac{\alpha' + \beta'}{1 - \rho'} \right) \hat{i}_0 \quad (2.35)$$

$$\hat{\pi} = \left[\theta' + \sigma' - \frac{\kappa'}{1 - \rho'}(\alpha' + \beta') \right] \hat{i}_0 \quad (2.36)$$

These new solutions are ambiguous as to their sign, magnitude and stability, not only because of what we said in the previous section, but also for the role played by the parameter ξ . Some preliminary considerations are now possible (proofs in Appendix). First, to keep the system stable ξ should be bounded as follows:

$$\xi < \frac{1 - \rho}{\alpha\kappa + (\theta - 1)(\rho - 1)} \quad (2.37)$$

If ξ satisfies this condition, the system converges to $[\hat{y}; \hat{\pi}]$. Otherwise the system may take different trajectories, some of which may be explosive. Second, if ξ satisfies the sign condition, the output gap \hat{y} has always the normal negative relationship with interest rate gap \hat{i}_0 , i.e. tighten monetary policy entails a drop in steady-state production compared to the potential level. Third, the inflation gap $\hat{\pi}$ has always positive/negative relationship with interest rate gap \hat{i}_0 , whatever the value of ξ . The sign of the gap is not due to inflation expectations but depends on the elasticity of the capital stock to the present and past interest rate (θ and σ). Forth, for structural values of the parameters the coefficient of \hat{y} decreases with ξ in absolute value, whereas the coefficient of $\hat{\pi}$ increases in absolute value. On the contrary, for empirical values of the parameters both the coefficients of \hat{y} and $\hat{\pi}$ increases with ξ in absolute value: short-run rational expectations amplify the deviation of the steady-state from the intertemporal equilibrium path. This last result illustrates the troublesome role of short-run rational expectations in cumulative processes. If we consider the case $\hat{i}_0 < 0$, this produce a positive output gap $\hat{y} > 0$. As agents anticipate higher inflation, the market *real* interest rate $r_t = i_t - E_t\pi_{t+1}$ is reduced further, increasing the gaps and so on. This expectation multiplier explains why short-run rational expectations are *deviation amplifying*. Fifth, the limit solution for $\xi \rightarrow 1$, is $[\hat{y}, \hat{\pi}] = [0, \hat{i}_0]$. There system “jumps” to an inflation gap equal to the interest-rate gap and forward-looking expectations are (self-)fulfilled. This case replicates the result of McCallum (1986). Using the so-called Fisher equation - namely $1 + i^{SS} = r^{SS}(1 + E_t\pi_{t+1})$ - he argues that if expected inflation is to be determined by postulating an exogenous nominal interest rate, it should be high as long as the nominal interest rate is high relative to the natural rate, and vice-versa. This conclusion holds only in intertemporal general equilibrium (Mazzocchi et al., 2009).

2.4 Dynamic properties: a quantitative assessment

In this paragraph I wish to inspect more closely the dynamic properties of the model (2.33)-(2.34) with the help of quantification of its parameters and some simulations. To this end I find convenient to look at some NNS-estimates of these parameters that can be found in the leading literature.

The structural model underlying the framework represents a theoretical competitive, flex-price economy. It hinges on the primitive parameter set (a, ρ, ξ, ψ) from which we could derive $(\alpha'; \beta', \kappa'; \theta'; \sigma')$. As far as the parameter set is concerned, we should consider that the NNS literature includes the sticky-price hypothesis, which leads to

Paper	a	α	β	ξ	θ	σ	ρ	κ (sticky)	κ (flex)
Laubach - Williams (2003)	-	0.10	0.10	-	-	-	0.45	0.05	-
Garnier - Wilhelmsen (2005)	-	0.18	0.07	-	-	-	0.45	0.10	-
Rotemberg - Woodford (1997)	-	0.16	-	-	-	-	0.40	0.02	-
Orphanides - Williams (2002)	-	0.02	-	0.50	-	-	0.47	0.14	-
McCallum - Casares (2000)	-	0.21	0.12	-	0.13	-	0.38	0.11	-
Tamborini (2010)	0.40	0.15	-	0.50	-	-	0.33	0.10	0.67
This Model	0.40	0.20	0.10	0.50	0.10	0.10	0.40	0.10	0.70

Table 2.2 – Available estimates of the model’s parameters

a different determination of the inflation-gap/output-gap elasticity, namely κ . The theoretical models as well as empirical evidence show that the combination of imperfect competition and sticky prices determines smaller elasticity of inflation gaps to output gaps than in the perfect competition and flex-price model we presented in the previous sections. Therefore I decide to organize the parametrization of the model around these two alternative hypothetical economies: the “theoretical” flex-price economy where $\kappa = \frac{a}{1-a}$ and the “empirical” sticky-price, for which κ is taken from available estimates.

As to the remaining parameters of interest, we simply quantify the capital income share a with the conventional value 0.4. Estimates of this parameter have a long-standing controversial history (Felipe and Adams, 2005). In particular, the capital income share in developed countries seems to be increasing as a result of globalization. However, this conventional benchmark is still largely used and is probably not too unrealistic. Selected estimates of other parameters are organized in Table 2.2. The second key parameters are the elasticity of the capital stock to the present and past interest rate θ and σ . Theoretically, these two parameters depend on the capital-income share a and the adjustment costs ψ : the higher are these two variables, the lower is the value of θ . Among other things, the high theoretical value of θ is due to the assumption that the capital stock fully depreciates in each period and should ultimately be replaced every year. Thus θ can be interpreted as the responsiveness of investment to the interest rate, and not as the elasticity of the capital stock. However, empirically the value of θ is much lower, since the portion of capital which has not depreciated $(1 - \delta)K_t$ is

Weight of short-term rational expectations	Sticky-price parametrization ($\kappa=0.1$)	Intermediate-case parametrization ($\kappa=0.4$)	Flex-price parametrization ($\kappa=0.7$)
$\xi=0$	$\alpha'=0.20$ $\beta'=0.10$ $\rho'=0.40$ $\theta'=0.10$ $\sigma'=0.10$ $\kappa'=0.10$	$\alpha'=0.20$ $\beta'=0.10$ $\rho'=0.40$ $\theta'=0.10$ $\sigma'=0.05$ $\kappa'=0.40$	$\alpha'=0.20$ $\beta'=0.10$ $\rho'=0.40$ $\theta'=0.20$ $\sigma'=0.10$ $\kappa'=0.70$
$\xi=0.5$	$\alpha'=0.19$ $\beta'=0.09$ $\rho'=0.40$ $\theta'=0.18$ $\sigma'=0.18$ $\kappa'=0.18$	$\alpha'=0.20$ $\beta'=0.09$ $\rho'=0.43$ $\theta'=0.18$ $\sigma'=0.18$ $\kappa'=0.73$	$\alpha'=0.21$ $\beta'=0.09$ $\rho'=0.46$ $\theta'=0.18$ $\sigma'=0.18$ $\kappa'=1.27$
$\xi=0.9$	$\alpha'=0.12$ $\beta'=0.06$ $\rho'=0.44$ $\theta'=0.53$ $\sigma'=0.53$ $\kappa'=0.53$	$\alpha'=0.17$ $\beta'=0.08$ $\rho'=0.64$ $\theta'=0.53$ $\sigma'=0.53$ $\kappa'=2.10$	$\alpha'=0.31$ $\beta'=0.02$ $\rho'=1.19$ $\theta'=0.53$ $\sigma'=0.53$ $\kappa'=3.68$

Table 2.3 – Parameter grid

substantially insensitive to changes of the interest rate. Unless otherwise stated, we shall thus assume $\theta = 0.1$ and $\sigma = 0.1$.

The last key parameter is ξ . It will be useful to consider the two extreme theoretical values of 0 (only long run expectations) and 1 (only short-run expectations). Since this last value implies a discontinuity that prevents computable simulations, it will be approximated by 0.9. Hence our parameter grid can eventually be generated by different “theoretical” and “empirical” combinations of (κ, ξ) as in the Table 2.3.

The two extreme cases correspond, respectively, to an economy closer to the New-Neoclassical paradigm (NCM) of perfect flexible prices and short-run rational expectations ($\kappa = 0.7$, $\xi = 0.9$) and to an economy closer to the Old Neoclassical Synthesis (ONS) with sticky prices and static long-run expectations ($\kappa = 0.1$, $\xi = 0$). As we will see, the more the economy comes closer to the NCM paradigm, the more the model becomes anomalous and eventually unstable. Let me assume a negative interest rate gap of 100 basis points, $\hat{i}_t = -100$. The ONS economy smoothly settles down two non-zero output and inflation gaps given by (2.35) and (2.36). The impact effect of interest rate shocks is very big both on output and inflation. This is due to the *time-to-build* hypothesis that assumes a lag between the installation of production capacity and its ability to be used. Therefore the change in interest rate causes a shift in aggregate demand while aggregate supply will adjust with a delay, in part also because of the presence of adjustment costs of capital. Too low nominal interest rate ends up with too high level of output but with an almost unchanged inflation rate (or with a slight

deflation). The latter result is the combined effect of the adjustment of the capital stock and the low elasticity κ (Figure 2.1).

The NCM economy for $\xi > 0.88$ is instead driven on an unstable, explosive path whereby both output and inflation gaps grow exponentially (see equation (2.37)). Although the simulation (Figure 2.2) does not impose a resources constraint to the output gap, we can assume that sooner or later it becomes binding. In this last case the simulation accounts for Wicksell's well-known concern with the pure inflationary effects of dynamic expectations: “[A]s long as the changes in prices is believed to be temporary, it will in fact remain permanent; as soon as it is considered to be permanent, it will become progressive, and when it is eventually seen progressive it will turn into an avalanche”. (Wicksell, 1922; p. XII, n.1). Of course, starting from too high nominal interest rate $\hat{i} = 100$ would yield the specular results with bottomless real and nominal downward spiral for the Neoclassical economy. This latter result vindicates Keynes's claim that flexible prices and wages - together with short-run dynamic expectations - would worsen the perverse effect of a saving-investment imbalances process triggered by a wrong interest rate (Keynes, 1936, ch. 12).

Finally, the economy portrayed by the NNS paradigm lies somewhere in between, as it can be identified with a combination of the ONS and NMC cases ($\kappa = 0.4$, $\xi = 0.5$). A negative interest rate gap will lead to a positive output gap and a slight inflation (Figure 2.3). The effect on inflation will depend mainly on the parameter θ . If θ is big enough it is not excluded that the final result will not take the form of inflation, although latent inflationary pressures would normally exist, rather it could be an outright deflation. Analyses in a Wicksellian vein of 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, one that has probably played a role in driving monetary policy onto a wrong track. The evidence seems to contradict the conventional wisdom (Bordo et al., 2000; Howitt, 2012) according to which saving-investment imbalances will not develop in a low and stable inflation environment. Indeed the combination of strong economic growth and low inflation can lead to overly optimistic expectations about the future which could generate increases in credit markets significantly beyond those justified by the original improvement in productivity. Yet, a self-reinforcing boom can emerge supporting, at least for a while, the optimistic expectations. While the stronger demand can put upward pressure on inflation, this pressure can be masked or totally offset by the improvement to the supply side of the economy (Figure 2.4).

2.5 Conclusions

The core of the NNS is mostly presented as a three-equation model that combines an intertemporal IS relation with an aggregate-supply (AS) function in terms of a New Keynesian Phillips curve and a Taylor rule for monetary policy. Most macroeconomists nowadays consider it as a general theory of inflation and output dynamics that is capable of generating highly stylized and yet empirically plausible models for policy evaluation. Particular interest has been elicited by Woodford's argument that the NNS policy implications are a modern restatement and refinement of the basic tenets of Wicksell's theory of monetary policy, as in *Interest and Prices* (1898b). One extension of NNS model includes explicit investment dynamics that show how monetary policy can have supply-side effects by way of affecting the productive capacity of the economy.

The NNS framework is - both in its neo-Wicksellian and other versions - precariously based on combinations of continuous intertemporal equilibrium under rational expectations with specific concepts of wage and price stickiness, and other assumptions. The qualifying features of old macroeconomic mainstreams are remarkably absent. While banks play a key role as intermediaries between savers and investors in the real world, the underlying frictions - relative to the Walrasian equilibrium benchmark - are considered only in some of the latest contributions of the NNS (Goodfriend and McCallum, 2007; Curda and Woodford, 2009; Christiano et al., 2010b). Likewise, the problems of limited information that produce the dynamics of money creation, income and prices - i.e. the so-called "cumulative process" - are largely excluded from the NNS perspective. These limitations do not allow NNS models to deal with the kind of spillovers and feedbacks that seem to characterized modern economies.

In the chapter I have presented a dynamic model in which cycles are driven by *saving-investment imbalances*. Interest-rate gaps in any period t give rise to an intertemporal spillover effect, i.e. a sequence of output and inflation gaps. This is a major difference with the NNS model where interest-rate gaps are associated with contemporaneous output gaps only and therefore future output gaps only depend on future interest-rate gaps. Moreover interest-rate gaps produce nominal as well as real effects (gaps) even in a competitive, flex-price economy: this is essentially a Keynesian result, which again marks a major difference with the NNS model - where real effects are only ascribed to sticky prices - but also with Wicksell himself, who did not consider - though did not deny either - real effects³⁵. Lastly, (excess) inflation or deflation are *disequilib-*

³⁵Wicksell made incidental mention of the real side of the "cumulative process" (Wicksell, 1898b,

rium phenomena in three distinct, but interconnected, meanings: a) excess investment or saving are being accommodated at the “wrong” real interest rate, b) the goods market clears at the “wrong” levels of output and inflation, c) the expected inflation rate is “wrong” with respect to the actual inflation rate.

The focus of the alternative framework presented in this paper 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 requirements 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 that may have a role to play (Greenwald and Stiglitz, 2003; 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 - the system will converge to a different steady-state equilibrium with output and inflation to be inefficiently high/low with respect to the intertemporal general equilibrium. The extent and magnitude of these gaps will depend, among other things, on the presence or absence of nominal rigidities and on the agents’ expectations. Approaching the Neoclassical case with rational expectations and perfect price flexibility, the system becomes more unstable and volatile and, in some cases, it may take divergent trajectories some of which may be explosive. Conversely, if the system has the typical old-Keynesian characteristics - i.e. static long-run expectations and sticky prices - it becomes more stable and predictable.

In general, 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-invests, the stock of physical capital and thus the productive capacity increases. As a result output grows, excess demand is offset over time and inflation is damped. This type of prediction is like the one made by Casares and McCallum (2000), where the output gap is very sensitive to interest rate, whereas the opposite can be said of inflation. This result can have very important implications in terms of monetary policy. Indeed the authorities may not be able to identify the financial imbalances sufficiently early and

p.77). It was Keynes, with his principle of effective demand, who understood that as long as the market real interest rate is “wrong” (e.g. too high) output should take care of adjusting excess saving no matter how deep deflation may be (Keynes, 1936, ch.19). Later, Lindahl (1939), drawing on Wicksell’s theory, included unemployment in his analysis, foreshadowing the modern distinction between cyclical and structural unemployment (Boianovsky and Trautwein, 2006a).

with the required degree of comfort to take remedial action. As Leijonhufvud (2007) recently said, the traditional inflation targeting strategy (Svensson, 2010) pursued by many central banks around the world not only will not protect by itself against financial instability, but it might mislead into pursuing a policy that could actively damaging financial stability. Recent episodes in the US seem to confirm this view. Probably there has been over-optimism in the NNS paradigm as if it were “End of History” of central banking (Tamborini, 2010b).

Although we have not explicitly treated the problem of monetary policy, we can draw some preliminary insights. In a context of imperfect information the dramatic distinction between “rules” and “discretion” is perhaps a semantic question. 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: none of the traditional rules produces good results if the central bank is misinformed about this variable. 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).

Appendix

Interest rate gaps and output gaps

Here I provide the proof of Proposition 2, and the allocations that result if, starting in the steady state, the market real interest rate at time t , R_{t+1} , differs from the natural rate R^{SS} . Both rates are assumed to remain constant thereafter.

To begin with, let me recall that the intertemporal general equilibrium is a steady state characterized by fully employed labour force $L^{SS} = 1$, an expected inflation rate $\pi^e = \pi^{SS} \geq 0$, households' time discount factor equal to the gross real return to the natural interest rate $\Theta = R^{SS}$, constant consumption C^{SS} , constant real stock of bonds representative of capital stock $B^{SS} = K^{SS}$, households' real income given by labour and capital incomes $Y^{SS} = H^{SS} + R^{SS}K^{SS}$. Note that, as a consequence, gross saving and gross investment equal K^{SS} , i.e. $S'_t = I'_t = K^{SS}$, and once account is taken of capital replacement, net investment and saving are equal and nil.

Turning now to a period t in which, ceteris paribus, $R_{t+1} \neq R^{SS}$, I first examine households' optimal consumption path:

$$C_t = E_t \left[\frac{C_{t+1}}{R_{t+1}} R^{SS} \right] \quad (2.38)$$

Therefore, from the main text we know that:

$$S'_t = H_t + R_t K_t - C_t \quad (2.39)$$

Now let me see the notional investment of firms, that is:

$$I'_t = K_{t+1} = \left(\frac{a}{R_{t+1}} \right)^{\frac{1}{1-a}} \quad (2.40)$$

Following the same procedure as in Smith and Wickens (2006), I plug each period budget constraint (2.39) into households Euler equation (2.38):

$$H_t + R_t K_t - B_{t+1} = E_t \left[\frac{H_{t+1} + R_{t+1} B_{t+1} - B_{t+2}}{R_{t+1}} R^{SS} \right] \quad (2.41)$$

The saving-investment inconsistency leads to $B_{t+s} \neq K_{t+s}$, for $s = 1, \dots, \infty$, where the real value of the stock of bonds purchased by households differs from the actual

stock of capital goods purchased by firms at each point in time. By contrast, as long as $R_{t+1} \neq R^{SS}$ the actual consumption path consistent with $B_{t+s} = K_{t+s}$ should satisfy:

$$Y_t - K_{t+1} = E_t \left[(Y_{t+1} - K_{t+2}) \frac{R^{SS}}{R_{t+1}} \right] \quad (2.42)$$

where $Y_t = H_t + R_t K_t$ and $Y_{t+1} = H_{t+1} + R_{t+1} K_{t+1}$.

Given that K_{t+1} is predetermined in t and that R_{t+1} remains constant with no other shock occurring, we have $E_t K_{t+2} = K_{t+1}$ and

$$Y_t = E_t Y_{t+1} \frac{R^{SS}}{R_{t+1}} + K_{t+1} \left(1 - \frac{R^{SS}}{R_{t+1}} \right) \quad (2.43)$$

which is equation (2.13) in the main text.

Now let me re-express equation (2.43) in terms of gaps by dividing both sides by Y^{SS} , denoting $\hat{Y} \equiv \frac{Y_t}{Y^{SS}}$, and in terms of the interest-rate gap as of t denoted by $\hat{R}_t \equiv \frac{R_{t+1}}{R^{SS}}$. Therefore:

$$\hat{Y}_t = E_t \hat{Y}_{t+1} \hat{R}_t^{-1} + \frac{K_{t+1}}{Y^{SS}} (1 - \hat{R}_t^{-1}) \quad (2.44)$$

Let me first develop the expectational term $E_t \hat{Y}_{t+1}$. This is in fact known with certainty as of t . Recall that $E_t Y_{t+1} = K_{t+1}^a E_t L_{t+1}^{1-a}$, $Y^{SS} = (K^{SS})^a (L^{SS})^{1-a}$. By the assumption of continuous full employment, $E_t L_{t+1}^{1-a} = L^{SS} = 1$. Hence Y_{t+1} is predetermined by the capital stock K_{t+1} chosen by firms in t , and therefore, $E_t \hat{Y}_{t+1} = \left(\frac{K_{t+1}}{K^{SS}} \right)^a$. We know that $K_{t+1} = \left(\frac{a}{R_{t+1}} \right)^{\frac{1}{1-a}}$, $K^{SS} = \left(\frac{a}{R^{SS}} \right)^{\frac{1}{1-a}}$, so that:

$$E_t \hat{Y}_{t+1} = \hat{R}_t^{-\frac{a}{1-a}} \quad (2.45)$$

Using the same previous relationship we can develop the second right hand side term in (2.44), i.e. $\frac{K_{t+1}}{Y^{SS}} = \frac{\left(\frac{a}{R_{t+1}} \right)^{\frac{1}{1-a}}}{\left(\frac{a}{R^{SS}} \right)^{\frac{1}{1-a}}}$. Substituting this expression and $E_t \hat{Y}_{t+1}$ into (2.44), after some algebraic manipulations we obtain:

$$\hat{Y}_t = \hat{R}_t^{-\frac{a}{1-a}} [1 - a (R_{t+1}^{-1} - R^{SS-1})]$$

If the rates are sufficiently small, the multiplicative term in parentheses is close to unity,

so that:

$$\hat{Y}_t \approx \hat{R}_t^{-\frac{1}{1-a}} \quad (2.46)$$

In order to obtain a log-linear transformation of deviations from the intertemporal general equilibrium steady-state as in standard NNS models, I will employ the usual Uhlig's procedure (Uhlig, 1999) to (2.43). It will be seen that the result is equivalent to directly taking the logarithms of expressions (2.45)-(2.46)³⁶. Log-deviations are denoted by small-case letters. Therefore:

$$Y^{SS}(1 + \hat{y}_t) = E_t \left[Y^{SSa}(1 + \hat{y}_{t+1})(1 - \hat{r}_t) + K^{SS}(1 + \hat{k}_{t+1})\hat{r}_t \right]$$

Dividing for Y^{SS} :

$$1 + \hat{y}_t = E_t \left[(1 + \hat{y}_{t+1})(1 - \hat{r}_t) + \phi(1 + \hat{k}_{t+1})\hat{r}_t \right] \quad (2.47)$$

where $\phi = \frac{K^{SS}}{Y^{SS}} = \left(\frac{a}{R^{SS}}\right)$. Now let me proceed by ignoring the second-order non-linear terms $E_t \hat{y}_{t+1} \hat{r}_t$, $\phi \hat{r}_t$, $\phi \hat{k}_t \hat{r}_t$, so that we can use the following approximation³⁷:

$$\hat{y}_t \approx E_t \hat{y}_{t+1} - \hat{r}_t \quad (2.48)$$

To compute $E_t \hat{y}_{t+1}$ consider that:

$$E_t [Y^{SS}(1 + \hat{y}_{t+1})] = K^{SSa} (1 + a\hat{k}_{t+1})$$

$$\hat{y}_{t+1} = a\hat{k}_{t+1} \quad (2.49)$$

Likewise, knowing that $K_{t+1} = \left(\frac{a}{R_{t+1}}\right)^{\frac{1}{1-a}}$, $K^{SS} = \left(\frac{a}{R^{SS}}\right)^{\frac{1}{1-a}}$, we obtain:

$$\hat{k}_{t+1} = -\frac{1}{1-a} \hat{r}_t$$

³⁶Any variable X_t can be expressed as a deviation factor \hat{X}_t from its steady-state value X^{SS} , i.e. $X_t = X^{SS} \hat{X}_t$. The deviation rate is $\hat{X}_t - 1$ and, if "sufficiently small", it can be approximated by the natural logarithm $\hat{x}_t = \ln X_t - \ln X^{SS}$, such that by approximation, $X_t \approx X^{SS} (1 + \hat{x}_t)$. Any variable $Z_t = F(X_t)$ can be approximated by $Z_t \approx F(X^{SS})(1 + \ln F(\hat{X}_t))$.

³⁷The capital-output ratio in steady state is a decimal number. Indeed $\phi = \frac{K^{SS}}{Y^{SS}} = \frac{a}{R^{SS}} = \frac{a}{\Theta}$, where $0 < a < 1$ and $\Theta > 1$.

so that

$$\hat{y}_{t+1} = -\frac{a}{1-a}\hat{r}_t$$

Substituting this expression into (2.48),

$$\hat{y}_t \approx -\frac{1}{1-a}\hat{r}_t$$

I now show that this sequence of output gaps, being driven by the common factor \hat{r}_t , can be expressed in a single linear combination behaving like a first-order autoregressive process. Let me denote with $z_1 = \frac{a}{a-1}$ and $z_2 = \frac{1}{a-1}$:

$$\begin{aligned}\hat{y}_{t+1} &= z_1\hat{r}_t \\ \hat{y}_t &= z_2\hat{r}_t\end{aligned}$$

We can write:

$$\hat{y}_{t+1} = \rho\hat{y}_t - \alpha\hat{r}_t \quad (2.50)$$

for an appropriate linear combination of parameters where ρ can be interpreted as a spurious correlation between \hat{y}_{t+1} and \hat{y}_t ³⁸. We have that:

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

We know that $\hat{r}_t = r_t - r^{SS}$. Thus, if $r_t = i_t - \pi_{t+1}^e$, then we could write $\hat{i}_t = i_t - \pi_{t+1}^e - r^{SS}$. That is:

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

which is equation (2.17) in the main text.

Inflation gaps

Firstly, as a result of the assumed Cobb-Douglas technology profit-maximizing output in any t can be expressed as:

$$Y_t = K_t \left(\frac{1-a}{\omega_t} \right)^{\frac{1-a}{a}} \quad (2.51)$$

³⁸We have that $\rho\hat{y}_t - \alpha\hat{r}_t = z_1\hat{r}_t$, thus $\alpha = z_2\rho - z_1$.

where $w_t = \frac{W_t}{P_t}$ is the current real wage rate, W_t is the nominal one and P_t is the output price.

Secondly, according to the labour market model in the main text, the nominal wage rate for $t + 1$ is given by indexing the full-employment real wage rate ω_{t+1} with the expected inflation rate π_{t+1}^e , i.e. $W_{t+1} = \omega_{t+1}P_t(1 + \pi_{t+1}^e)$. Firms can still adjust output in $t + 1$ up to the point where the ensuing marginal product of labour equates the actual real wage rate $w_{t+1} = \frac{W_{t+1}}{P_{t+1}}$, where $P_{t+1} = P_t(1 + \pi_{t+1})$. As a result,

$$Y_{t+1} = K_{t+1} \left(\frac{1 - a}{\omega_{t+1}} \frac{1 + \pi_{t+1}}{1 + \pi_{t+1}^e} \right)^{\frac{1-a}{a}} \quad (2.52)$$

Ceteris paribus, profit-maximizing firms are ready to expand/contract output as long as π_{t+1} , being greater/smaller than π_{t+1}^e , reduces/increases the actual real wage rate with respect to ω_{t+1} . Conversely, we can derive the Marshallian supply curve of firms, that is, the inflation gap $\hat{\Pi}_{t+1} \equiv \frac{1 + \pi_{t+1}}{1 + \pi_{t+1}^e}$ which supports a given output gap. Let me divide (2.52) for Y^{SS} :

$$\frac{Y_{t+1}}{Y^{SS}} = \frac{K_{t+1}}{Y^{SS}} \left(\frac{1 - a}{\omega^*} \frac{1 + \pi_{t+1}}{1 + \pi_{t+1}^e} \right)^{\frac{1-a}{a}}$$

Setting $\hat{Y}_{t+1} = \frac{Y_{t+1}}{Y^{SS}}$ and $\tilde{\Pi}_{t+1} = \frac{\Pi_{t+1}}{\Pi_{t+1}^e}$ we have:

$$\hat{Y}_{t+1} = \hat{K}_{t+1} \frac{1}{\left(\frac{1-a}{\omega^*}\right)^{\frac{1-a}{a}}} \left(\frac{1 - a}{\omega^*} \tilde{\Pi}_{t+1} \right)^{\frac{1-a}{a}}$$

and therefore:

$$\hat{Y}_{t+1} = \hat{K}_{t+1} \left(\tilde{\Pi}_{t+1} \right)^{\frac{1-a}{a}}$$

and thus:

$$\tilde{\Pi}_{t+1} = \left(\frac{\hat{Y}_{t+1}}{\hat{K}_{t+1}} \right)^{\frac{a}{1-a}}$$

which is equation (2.16) in the main text. Log-linearizing the expression:

$$\tilde{\pi}_{t+1} = \frac{a}{1-a} \hat{y}_{t+1} - \frac{a}{1-a} \hat{k}_{t+1}$$

which is equation (2.19) in the main text.

Adjustment costs of capital

Let me start from equations (2.47)-(2.49). Substituting equation (2.28) we have:

$$\begin{aligned}\hat{y}_{t+1} &= a((1-\psi)\hat{k}_{t+1}^* + \psi\hat{k}_t^*) \\ 1 + \hat{y}_t &= E_t \left[(1 + a((1-\psi)\hat{k}_{t+1}^* + \psi\hat{k}_t^*))(1 - \hat{r}_t) \right] + \\ &\quad + E_t \left[\phi(1 + ((1-\psi)\hat{k}_{t+1}^* + \psi\hat{k}_t^*))\hat{r}_t \right]\end{aligned}$$

Moreover we know that $\hat{k}_{t+1} = -\frac{1}{1-a}\hat{r}_t$, thus:

$$\begin{aligned}\hat{y}_{t+1} &= \frac{a\hat{r}_{t-1}\psi}{a-1} + \frac{a\hat{r}_t(1-\psi)}{a-1} \\ 1 + \hat{y}_t &= 1 + \frac{\hat{r}_{t-1}\hat{r}_t\phi\psi}{a-1} + \frac{a\hat{r}_{t-1}\hat{r}_t\psi}{1-a} + \frac{a\psi\hat{r}_{t-1}}{a-1} + \frac{\hat{r}_t^2\phi(1-\psi)}{a-1} + \frac{a\hat{r}_t^2(\psi-1)}{a-1} + \\ &\quad + \hat{r}_t\phi + \frac{\hat{r}_t(a\psi-1)}{1-a}\end{aligned}$$

where I dropped the expectation operator from the second equation since $E_t k_{t+1} = k_{t+1}$. The quadratic terms \hat{r}_t^2 and the product of the two decimal numbers $\hat{r}_t \cdot \phi$ and $\hat{r}_t^2 \cdot \phi$ are small log-deviations and therefore can be neglected. We get:

$$\begin{aligned}\hat{y}_{t+1} &= \frac{a(1-\psi)}{a-1}\hat{r}_t + \frac{a\psi}{a-1}\hat{r}_{t-1} \\ \hat{y}_t &\approx \frac{a\psi-1}{1-a}\hat{r}_t + \frac{a\psi}{a-1}\hat{r}_{t-1}\end{aligned}$$

Let me denote with $z_1 = \frac{a(1-\psi)}{a-1}$, $z_2 = \frac{a\psi}{a-1}$, $z_3 = \frac{a\psi-1}{1-a}$ and $z_4 = \frac{a\psi}{a-1}$:

$$\begin{aligned}\hat{y}_{t+1} &= z_1\hat{r}_t + z_2\hat{r}_{t-1} \\ \hat{y}_t &= z_3\hat{r}_t + z_4\hat{r}_{t-1}\end{aligned}$$

We can write:

$$\hat{y}_{t+1} = \rho\hat{y}_t - \alpha\hat{r}_t - \beta\hat{r}_{t-1} \tag{2.53}$$

for an appropriate linear combination of parameters α and β and where ρ can be interpreted as a spurious correlation between \hat{y}_{t+1} and \hat{y}_t ³⁹. We have that:

$$\begin{aligned}\alpha &= \frac{\rho - a[1 + \psi(\rho - 1)]}{a - 1} \\ \beta &= \frac{a\psi(\rho - 1)}{a - 1}\end{aligned}$$

We know that $\hat{r}_t = r_t - r^{SS}$. Thus, if $r_t = i_t - \pi_{t+1}^e$, then we could write $\hat{i}_t = i_t - \pi_{t+1}^e - r^{SS}$. That is:

$$\hat{y}_{t+1} = \rho\hat{y}_t - \alpha\hat{i}_t - \beta\hat{i}_{t-1}$$

which is equation (2.29) in the main text.

Let me consider now equations (2.18) and (2.28). Combining these two equations we get:

$$\pi_{t+1} = \pi_{t+1}^e + \frac{a}{1-a}\hat{y}_{t+1} + \frac{a}{(1-a)^2} \left[(1-\psi)\hat{i}_t + \psi\hat{i}_{t-1} \right]$$

and setting $\tilde{\pi}_{t+1} = \pi_{t+1} - \pi_{t+1}^e$, $\kappa = \frac{a}{1-a}$, $\theta = \frac{a(1-\psi)}{(1-a)^2}$ and $\sigma = \frac{a\psi}{(1-a)^2}$ we get:

$$\tilde{\pi}_{t+1} = \kappa\hat{y}_{t+1} + \theta\hat{i}_t + \sigma\hat{i}_{t-1}$$

which is equation (2.30) in the main text.

Inflation expectations

I can write equations (2.17) and (2.29) as follows:

$$\hat{y}_{t+1} = \rho\hat{y}_t - \alpha(i_t - \pi_{t+1}^e - r^*) - \beta\hat{i}_{t-1} \quad (2.54)$$

$$\pi_{t+1} - \pi_{t+1}^e = \kappa\hat{y}_{t+1} + \theta(i_t - \pi_{t+1}^e - r^*) + \sigma\hat{i}_{t-1} \quad (2.55)$$

Since $E_t\pi_{t+1} - \pi_{t+1} = 0$ (*short run rational expectation hypothesis*), I substitute $\pi_{t+1}^e = \xi\pi_{t+1} + (1-\xi)\pi^*$ in the (2.55) and I get:

$$\pi_{t+1} - \xi\pi_{t+1} - (1-\xi)\pi^* = \kappa\hat{y}_{t+1} + \theta\hat{i}_t - \theta\xi(\pi_{t+1} - \pi^*) + \sigma\hat{i}_{t-1}$$

³⁹We have that $\rho\hat{y}_t - \alpha\hat{r}_t - \beta\hat{r}_{t-1} = z_1\hat{r}_t + z_2\hat{r}_{t-1}$, thus $\alpha = z_3\rho - z_1$ and $\beta = z_4\rho - z_2$.

e then, by setting $\hat{\pi}_{t+1} = \pi_{t+1} - \pi^*$, I have:

$$\hat{\pi}_{t+1} = \kappa' \hat{y}_{t+1} + \theta' \hat{i}_t + \sigma' \hat{i}_{t-1} \quad (2.56)$$

where

$$\begin{aligned} \kappa' &= \frac{\kappa}{1 - \xi(1 - \theta)} \\ \theta' &= \frac{\theta}{1 - \xi(1 - \theta)} \\ \sigma' &= \frac{\sigma}{1 - \xi(1 - \theta)} \end{aligned}$$

Let me reconsider equation (2.54). By similar substitutions I have:

$$\hat{y}_{t+1} = \rho \hat{y}_t - \alpha \hat{i}_t + \alpha \xi \pi_{t+1} + \alpha(1 - \xi)\pi^* + \alpha r^* - \beta \hat{i}_{t-1}$$

thus:

$$\hat{y}_{t+1} = \rho \hat{y}_t - \alpha \hat{i}_t + \alpha \xi (\pi_{t+1} - \pi^*) - \beta \hat{i}_{t-1}$$

substituting I get:

$$\hat{y}_{t+1} = \rho \hat{y}_t - \alpha \hat{i}_t + \alpha \xi (\kappa' \hat{y}_{t+1} + \theta' \hat{i}_t + \sigma' \hat{i}_{t-1}) - \beta \hat{i}_{t-1}$$

and inserting the values of κ' , θ' and σ' I get:

$$\hat{y}_{t+1} = \rho' \hat{y}_t - \alpha' \hat{i}_t - \beta' \hat{i}_{t-1} \quad (2.57)$$

where:

$$\begin{aligned} \rho' &= \rho \frac{1 - \xi(1 - \theta)}{1 - \xi(1 + \alpha\kappa - \theta)} \\ \alpha' &= \alpha \frac{1 - \xi}{1 - \xi(1 + \alpha\kappa - \theta)} \\ \beta' &= \frac{\beta[1 - \xi(1 - \theta)] - \alpha\xi\sigma}{1 - \xi(1 + \alpha\kappa - \theta)} \end{aligned}$$

The model will then consist of the equations (2.34) and (2.34) in the main text.

Let me consider now the steady-state conditions (2.35) and (2.36). The steady-state output-gap is given by:

$$\hat{y} = \frac{\alpha' + \beta'}{1 - \rho'} \hat{i}_0 = \frac{\alpha + \beta - \xi [\alpha(1 + \sigma) + \beta(1 - \theta)]}{1 - \rho - \xi [\alpha\kappa + (\theta - 1)(\rho - 1)]} \hat{i}_0$$

this quantity is greater than zero only if:

$$\xi < \frac{\alpha + \beta}{\alpha(1 + \sigma) + \beta(1 - \theta)}$$

which is always satisfied for plausible values of the parameters.

Let me compute the effect of ξ on the output-gap:

$$\frac{\partial \hat{y}}{\partial \xi} = \frac{\alpha[(\alpha + \beta)\kappa + (\theta + \sigma)(\rho - 1)]}{[(1 - \xi(1 - \theta))(\rho - 1) + \alpha\kappa\xi]^2}$$

which is positive when $(\alpha + \beta)\kappa > (\theta + \sigma)(1 - \rho)$ and negative otherwise. It is simply to note that for structural values of the parameters, \hat{y} decreases when ξ increases. On the contrary, empirically an increase in ξ determines an increase in \hat{y} (in absolute value).

Let me consider now equation (2.36). The steady-state is:

$$\hat{\pi} = \hat{\pi} = \left[\theta' + \sigma' - \frac{\kappa'}{1 - \rho'} (\alpha' + \beta') \right] \hat{i}_0 = \frac{(\alpha + \beta)\kappa + (\theta + \sigma)(\rho - 1)}{(1 - \xi(1 - \theta))(\rho - 1) + \alpha\kappa\xi} \hat{i}_0$$

It is simply to check that this coefficient, whatever the value of ξ , is always greater than zero for the structural values of the parameters, while it could be negative if θ and σ are small. Moreover we have that:

$$\frac{\partial \hat{\pi}}{\partial \xi} = \frac{[(\alpha + \beta)\kappa + (\theta + \sigma)(\rho - 1)] \cdot [\alpha\kappa + (\theta - 1)(\rho - 1)]}{[(1 - \xi(1 - \theta))(\rho - 1) + \alpha\kappa\xi]^2}$$

An increase of ξ determines an increase (in absolute value) of $\hat{\pi}$. In other words, forward-looking expectations are *deviation-amplifying* in steady state.

Finally it is easy to show that the system converges to $[\hat{y}; \hat{\pi}]$ only if ξ satisfies the following condition:

$$\xi < \frac{1 - \rho}{\alpha\kappa + (\theta - 1)(\rho - 1)}$$

otherwise the system may take different trajectories, some of which may be explosive.

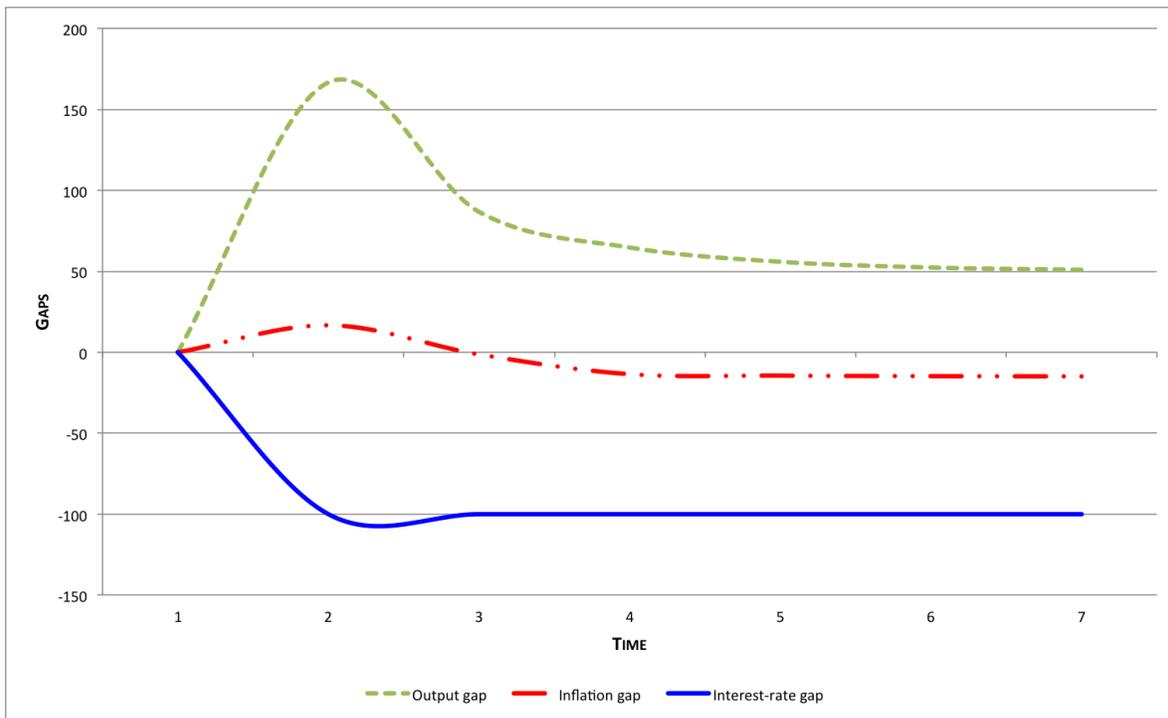


Figure 2.1 – Old Neoclassical Synthesis case - $\kappa = 0.1$, $\xi = 0$

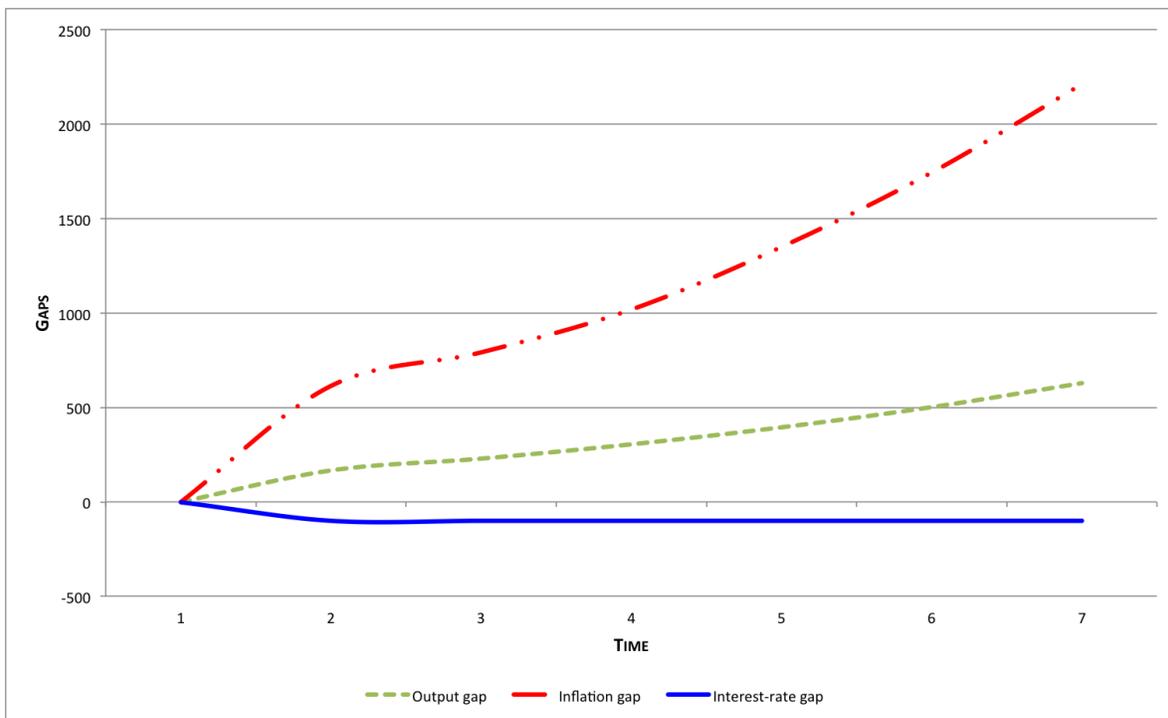


Figure 2.2 – Neoclassical case - $\kappa = 0.7$, $\xi = 0.9$

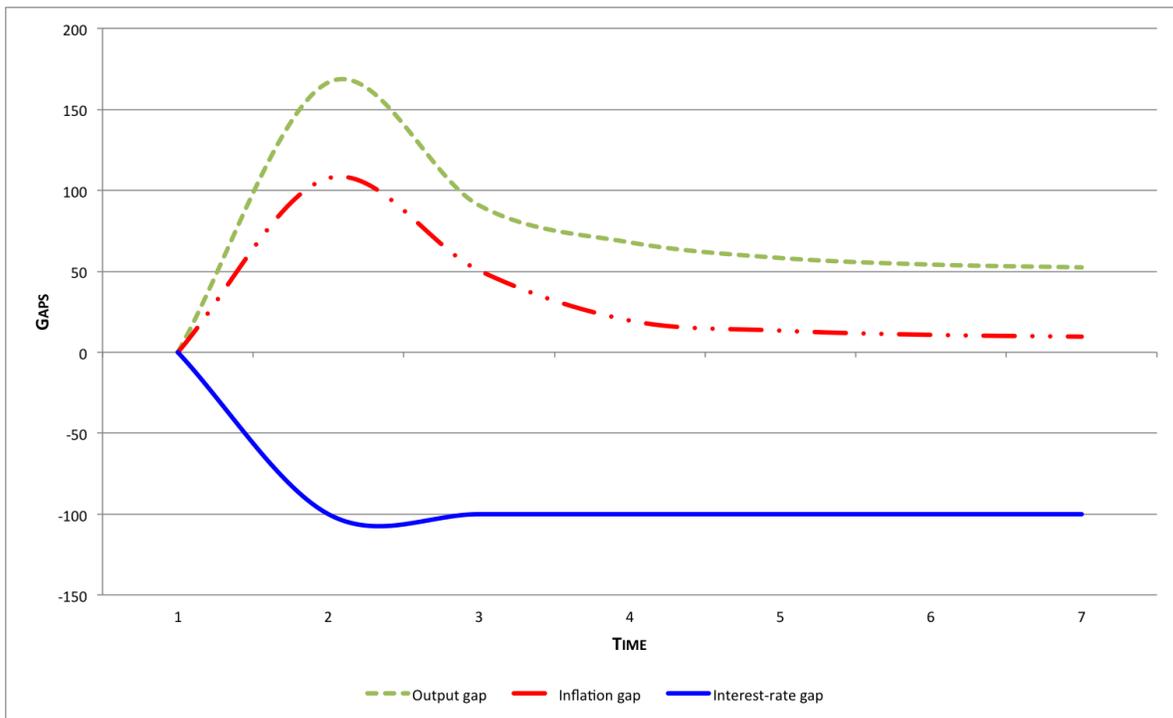


Figure 2.3 – Intermediate case - $\kappa = 0.4$, $\xi = 0.5$

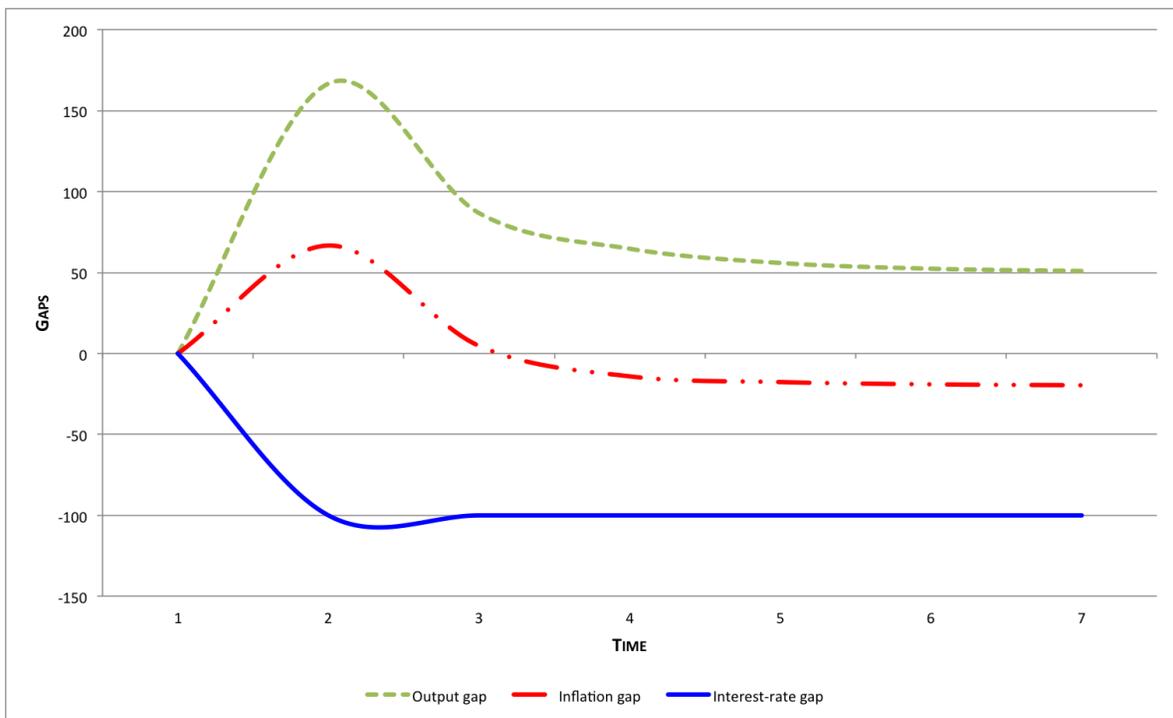


Figure 2.4 – High elasticity of capital stock to interest rate

Chapter 3

Intertemporal Coordination Failure and Monetary Policy

3.1 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) which has been expounded in Chapter 1. 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 (1979a) 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 authorities¹. This is a consequence of the pervasive theoretical and empirical research on the fact that independence helps to reduce inflation rates without any adverse consequences on output (Kydland and Prescott, 1977; Alesina and Summers, 1993)². 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)³. 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

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.

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 responsibilities 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 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 know 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 parameter” (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, 1898b, 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 signals⁴. 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 factors⁵ Overall they tend to create a positive association between favorable supply-side developments (which push down the prices) and asset price booms (easier access to external finance and optimistic assessment of risk)⁶. 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 infla-

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 perspectives, which can underpin a consumption and lending boom, often financed by inflow of foreign 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.

⁶In 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.

tion 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 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., 2010a; 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 chapter 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 (see Chapter 2). The main question to be addressed is whether an interest-rate rule is effective in stabilizing the economy in the event of investment-saving imbalances. Section [3.2] resumes the dynamic model with investment-saving imbalances of Chapter 2 focusing on the role of the interest-rate feedback rule. Section [3.3] explores the dynamic properties of the economic system with different interest-rate rules and establishes the properties of a stabilizing rule. Section [3.4] concludes.

3.2 The theoretical model

In this section I resume the dynamic model of Chapter 2 whereby it is possible to assess some basic issues concerning the macroeconomics of investment-saving imbalances. 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 behaviour 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 ω^{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} ; ω^{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 π^* 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 π_{t+1}^e and the observed market real interest rate $r_{t+1} = i_t - \pi_{t+1}^e$. 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 $i_t = i^{SS} + \pi_{t+1}^e$.

Our starting point is that the central bank may peg the wrong interest-rate level, i.e. $i_t \neq i^{SS} + \pi_{t+1}^e$. Given such interest-rate gap at time t , an investment-saving imbalance occurs in that households wish to save more ($i_t > i^{SS} + \pi_{t+1}^e$) or less ($i_t < i^{SS} + \pi_{t+1}^e$), 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 $n = 0, 1, \dots$ is necessary. As shown in Chapter 2, the output dynamics triggered by the initial interest-rate gap can be represented in a single first-order log-linearized equation like the following:

$$y_{t+1} = y^{SS} + \rho(y_t - y^{SS}) - \alpha(i_t - \pi_{t+1}^e - r^{SS}) \quad (3.1)$$

where α is the *feed-forward effect* of the interest-rate gap as of t on future output, and ρ 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 gap⁷. The steady-state of (3.1) is the output gap of the economy settles down after the initial interest-rate gap. As already mentioned in Chapter 2, 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 ρ . Notably, a dynamic structure like (3.1) 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, that 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 π_{t+1}^e 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 y^{SS} . The log-linear equation that represents the inflation path is:

$$\pi_{t+1} = \pi_{t+1}^e + \kappa(y_{t+1} - y^{SS}) + v(i_t - \pi_{t+1}^e - r^{SS}) \quad (3.2)$$

where κ denotes the link between output and inflation while v 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

⁷Recall 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.

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

the presence of non-zero interest-rate gap in (3.2) 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. For the reasons discussed in Chapter 2 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 π^* . A consistent representation is the following:

$$\pi_{t+1}^e = \xi \pi_{t+1} + (1 - \xi) \pi^* \quad (3.3)$$

The parameter $1 - \xi$ can also be interpreted as a degree of credibility of the central bank⁹.

The model composed by equations (3.1), (3.2) and (3.3) 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 $\hat{i}_t = i_t - i^{SS} = i_t - \pi^* - r^{SS}$:

$$\begin{aligned} \hat{y}_{t+1} &= \rho \hat{y}_t - \alpha \hat{i}_t + \alpha \xi \hat{\pi}_{t+1} \\ \hat{\pi}_{t+1} &= \frac{\kappa}{1 - \xi(1 - \nu)} \hat{y}_{t+1} + \frac{\nu}{1 - \xi(1 - \nu)} \hat{i}_t \end{aligned}$$

⁹As in Chapter 2, equation (3.3) 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 π^* 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 Δ_1 of having an inflation expectation other than $E_t \pi_{t+1}$, while the second can be interpreted as the cost Δ_2 of hot adjusting expectation with respect to long-term one π^* . Therefore in each period t agents faces the following cost function:

$$M_t = \Delta_1 (\pi_{t+1}^e - E_t \pi_{t+1})^2 + \Delta_2 (\pi_{t+1}^e - \pi^*)^2 \quad (3.4)$$

Minimizing with respect to π_{t+1}^e and setting $\xi = \frac{\Delta_1}{\Delta_1 + \Delta_2}$ we get exactly (3.3).

Setting:

$$\begin{aligned}\alpha' &= \alpha \frac{1 - \xi}{1 - \xi(1 + \alpha\kappa - v)} & v' &= \frac{v}{1 - \xi(1 - v)} \\ \rho' &= \rho \frac{1 - \xi(1 - v)}{1 - \xi(1 + \alpha\kappa - v)} & \kappa' &= \frac{\kappa}{1 - \xi(1 - v)}\end{aligned}$$

we get, in matrix form:

$$\begin{bmatrix} \hat{y}_{t+1} \\ \hat{\pi}_{t+1} \end{bmatrix} = \begin{bmatrix} \rho' & 0 \\ \kappa'\rho' & 0 \end{bmatrix} \begin{bmatrix} \hat{y}_t \\ \hat{\pi}_t \end{bmatrix} + \begin{bmatrix} -\alpha' \\ v' - \kappa'\alpha' \end{bmatrix} \hat{i}_t \quad (3.5)$$

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:

$$\hat{y} = - \left(\frac{\alpha'}{1 - \rho'} \right) \hat{i}_0 \quad (3.6)$$

$$\hat{\pi} = \left[v' - \frac{\kappa'\alpha'}{1 - \rho'} \right] \hat{i}_0 \quad (3.7)$$

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 κ'), that is, is independent of the degree of price flexibility¹⁰. 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

¹⁰As 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, 1898b, p. 80).

gaps along the adjustment path. This can be seen looking at the model. If ξ increases, both the coefficient of \hat{y} and $\hat{\pi}$ in equations (3.6)-(3.7) tend to become larger: short-run rational expectations 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 gap¹¹. 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 gap¹². 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 alter certain policy provisions provided by the NNS.

3.3 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 homogeneous 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

¹¹This 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).

¹²Of course, the adjustment path may consider also the delays due to time lag and/or adjustment costs of capital (see Chapter 2). 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.

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 (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.

3.3.1 The non-optimality of the optimal Taylor rule

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):

$$\min L_t = - \sum_{s=0}^{\infty} \frac{1}{2} [\eta_y (y_{t+s} - y^{SS})^2 + \eta_\pi (\pi_{t+s} - \pi^*)^2] \quad (3.8)$$

subject to:

$$\pi_t - \pi^* = \kappa'(y_t - y^{SS}) + v'(i_{t-1} - i^{SS})$$

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 η_π and

η_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:

$$i_t = i^{SS} + \gamma_y(y_t - y^{SS}) + \gamma_\pi(E_t\pi_{t+1}|i_{t-1} - \pi^*) \quad (3.9)$$

where

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

This formulation includes three targets (y^{SS} , i^{SS} , π^*). 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 γ_y and γ_π 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 (3.9). 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 (3.9) in gap terms. Together with equations (3.5), it 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.

$$\begin{bmatrix} \hat{y}_{t+1} \\ \hat{\pi}_{t+1} \\ \hat{i}_{t+1} \end{bmatrix} = \mathbf{A} \cdot \begin{bmatrix} \hat{y}_t \\ \hat{\pi}_t \\ \hat{i}_t \end{bmatrix} \quad (3.10)$$

where:

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

Hence the system supports a rational-expectations equilibrium in the target inflation rate π^* 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, 1898b). Keynes was even more radical, casting doubts on the existence itself of a single general equilibrium real rate of interest (Keynes, 1937a). 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 Wilhelmssen, 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 $\bar{i} = \tilde{i} - i^{SS}$ and $\bar{y} = \tilde{y} - y^{SS}$. The system that is obtained in this case is:

$$\begin{bmatrix} \hat{y}_{t+1} \\ \hat{\pi}_{t+1} \\ \hat{i}_{t+1} \end{bmatrix} = \mathbf{A} \cdot \begin{bmatrix} \hat{y}_t \\ \hat{\pi}_t \\ \hat{i}_t \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \bar{i} + \begin{bmatrix} 0 \\ 0 \\ -\gamma_y \end{bmatrix} \bar{y} \quad (3.11)$$

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 [3.2], 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.

Lagged information

Theoretically, under suitable realing 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 (3.10) 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 (3.9) 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 $\hat{x}_0 = \tilde{x}_0 - x^{SS}$ and $\tilde{x}_t - x^{SS} = 0$ (with $x = i, y$) for all $t > 0$. The dynamic process of the system is given by (3.10). As said above, this system admits a zero-gap steady-state solution $\mathbf{x} = 0$. To check for convergence note that by way of a chain of substitution into (3.10), we obtain:

$$\hat{i}_{t+1} = \left(\kappa' \frac{[v' - \kappa' \alpha'(1 + \rho')](1 - a) - \kappa' \rho'^2}{\alpha'(1 - a)} \eta_\pi - \rho' \frac{[\rho' + \alpha'(1 - a)]}{\alpha'(1 - a)} \eta_y \right) \hat{i}_t$$

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 5 *Given the structural parameters a , α' , ρ' , κ' , and v' , for the system to converge to, and to be stable around, the zero-gaps steady state, the parameters η_π and η_y should satisfy the following conditions:*

$$\alpha(a - 1) < \Upsilon_1 \kappa' \eta_\pi - \Upsilon_2 \rho' \eta_y < \alpha'(1 - a) \quad (3.12)$$

where:

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

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

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 (3.12) the boundedness principle is more stringent, the larger is parameter ξ , 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 a 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*. The main contributions of the literature on this subject say that γ_π 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 Wood-

ford (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. Let me see this point in the model. Knowing that $\hat{y}_t = \kappa'^{-1}(\hat{\pi}_t - v'\hat{i}_{t-1})$, simple algebraic manipulations of equation (3.10) yield:

$$\hat{i}_t = -\{\gamma_\pi[v'(\rho' - 1) + \kappa'\alpha'] + \gamma_y\kappa'^{-1}v'\}i_{t-1} + (\gamma_\pi\rho' + \gamma_y\kappa'^{-1})\pi_t$$

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

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

Upon substituting the appropriate expressions for γ_π and γ_y we get:

$$\eta_\pi\kappa'^2 + \eta_y > \frac{\alpha'\kappa'}{\rho'} \quad (3.13)$$

Obviously, this last condition may not be consistent with **Proposition 1**. Two relevant cases are possible. If condition (3.13) is compatible with (3.12), 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 η_π 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 η_π and η_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 v 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, 2010b). Conversely, if the responsiveness of capital to the interest rate is high - namely v 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 η_π and η_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 6 *Once the stability condition on the central bank's parameters has been satisfied, the system can achieve monotonic convergence only if:*

$$0 < \Upsilon_1 \kappa' \eta_\pi - \Upsilon_2 \rho' \eta_y < \alpha'(1 - a) \quad (3.14)$$

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 this dynamics is closely linked to the central bank's behaviour. If it delays on 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

Paper	a	α	ξ	u	ρ	κ (sticky)	κ (flex)
Laubach - Williams (2003)		0.10	-	-	0.45	0.05	-
Garnier - Wilhelmsen (2005)		0.18	-	-	0.45	0.10	-
Rotemberg - Woodford (1997)		0.16	-	-	0.40	0.02	-
Orphanides - Williams (2002)		0.02	0.50	-	0.47	0.14	-
McCallum - Casares (2000)		0.21	-	0.13	0.38	0.11	-
Tamborini (2010)	0.40	0.15	0.50	-	0.33	0.10	0.67
This Model	0.40	0.20	0.50	0.10	0.40	0.10	0.70

Table 3.1 – Available estimates of the model’s parameters

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.

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 (3.5) and (3.10). Selected estimates of parameters are taken from the leading NNS literature and are organized in Table 3.1.

I shall focus on two critical parameters that characterize the economic structure: the extent of short-term rational expectations measured by ξ and the degree of price flexibility reflected by κ . 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

¹³Since $\xi = 1$ implies a discontinuity that prevents computable simulations, it will be approximated by 0.9.

Weight of short-term rational expectations	Sticky-price parametrization $\kappa=0.1$	Intermediate-case parametrization $\kappa=0.4$	Flex-price parametrization $\kappa=0.7$
$\xi=0$	$\alpha'=0.20$ $\rho'=0.40$ $u'=0.10$ $\kappa'=0.10$	$\alpha'=0.20$ $\rho'=0.40$ $u'=0.10$ $\kappa'=0.40$	$\alpha'=0.20$ $\rho'=0.40$ $u'=0.10$ $\kappa'=0.70$
$\xi=0.5$	$\alpha'=0.19$ $\rho'=0.41$ $u'=0.18$ $\kappa'=0.18$	$\alpha'=0.20$ $\rho'=0.43$ $u'=0.18$ $\kappa'=0.73$	$\alpha'=0.21$ $\rho'=0.46$ $u'=0.18$ $\kappa'=1.27$
$\xi=0.9$	$\alpha'=0.12$ $\rho'=0.44$ $u'=0.53$ $\kappa'=0.53$	$\alpha'=0.17$ $\rho'=0.64$ $u'=0.53$ $\kappa'=2.11$	$\alpha'=0.31$ $\rho'=1.19$ $u'=0.53$ $\kappa'=3.68$

Table 3.2 – Parameters grid

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 3.2.

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 (3.12) to determine the upper bound of the output-gap parameter η_y . The relevant figures are given in Table 3.3.

The first important message is that different combinations of parameters (κ, ξ) 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 central bank should be conservative (low value of η_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 (κ, ξ) require *low* values of the compound inflation coefficient $\bar{\gamma}_\pi$ in the interest-rate rule.

To complete our quantitative assessment, let me provide in Figure 3.1-3.2-3.3 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

Weight of short-term rational expectations	Sticky-price parametrization $\kappa=0.1$	Intermediate-case parametrization $\kappa=0.4$	Flex-price parametrization $\kappa=0.7$
$\xi=0$	$\eta\gamma < 4.8$ $\gamma\pi = 0.5$ $\gamma\gamma < 9.6$	$\eta\gamma < 4.6$ $\gamma\pi = 2.0$ $\gamma\gamma < 9.2$	$\eta\gamma < 4.2$ $\gamma\pi = 3.5$ $\gamma\gamma < 8.4$
$\xi=0.5$	$\eta\gamma < 4.7$ $\gamma\pi = 0.9$ $\gamma\gamma < 10.3$	$\eta\gamma < 3.7$ $\gamma\pi = 3.7$ $\gamma\gamma < 8.1$	$\eta\gamma < 1.8$ $\gamma\pi = 6.1$ $\gamma\gamma < 3.9$
$\xi=0.9$	$\eta\gamma < 4.7$ $\gamma\pi = 4.5$ $\gamma\gamma < 17.8$	$\eta\gamma < -2.0$ $\gamma\pi = 12.4$ $\gamma\gamma < -7.6$	$\eta\gamma < -13.9$ $\gamma\pi = 12.4$ $\gamma\gamma < -7.6$

Table 3.3 – Optimal rule of the conservative central bank ($\eta_\pi = 1$). Values of the stability upper bound of η_y , and the implied values of the interest-rate rule coefficients

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.

3.3.2 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:

$$i_{t+1} = (1 - \gamma_i)i_t + \gamma_\pi(\pi_{t+1} - \pi^*) + \gamma_y(y_{t+1} - y_t) \quad (3.15)$$

Let us express the rule in terms of gaps:

$$\hat{i}_{t+1} = (1 - \gamma_i)\hat{i}_t + \gamma_\pi\hat{\pi}_{t+1} + \gamma_y(\hat{y}_{t+1} - \hat{y}_t) \quad (3.16)$$

This equation represents the hidden adjustment process ongoing in the economy, and now it is not implied that anyone knows it. Now equations (3.5) and (3.16) 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 $\gamma_\pi, \gamma_y, \gamma_i$. The following proposition holds:

Proposition 7 *With an adaptive interest-rate rule like (3.16), for the system to converge to the zero-gaps steady state, the policy coefficients should satisfy the following conditions:*

$$2(a - 1) < \Upsilon_3\gamma_\pi + [1 - \rho' - \alpha'(1 - a)]\gamma_y - (1 - a)\gamma_i < 0 \quad (3.17)$$

where

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

Weight of short-term rational expectations	Type of convergence	Sticky-price parametrization $\kappa=0.1$	Intermediate-case parametrization $\kappa=0.4$	Flex-price parametrization $\kappa=0.7$
$\xi=0$	Monotonic	$\gamma\pi < 7.5$	$\gamma\pi < 3.6$	$\gamma\pi < 1.7$
	Oscillatory	never	$\gamma\pi < 7.7$	$\gamma\pi < 3.7$
$\xi=0.5$	Monotonic	$\gamma\pi < 4.0$	$\gamma\pi < 1.8$	$\gamma\pi < 0.8$
	Oscillatory	never	$\gamma\pi < 3.9$	$\gamma\pi < 1.8$
$\xi=0.9$	Monotonic	$\gamma\pi < 1.2$	$\gamma\pi < 0.4$	$\gamma\pi < 0.1$
	Oscillatory	never	$\gamma\pi < 0.9$	$\gamma\pi < 0.2$

Table 3.4 – - Adaptive rule. Values of oscillatory and monotonic-stability upper bounds for γ_π assuming $\gamma_i = 0.1$ and $\gamma_y = 0$

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 γ_i , γ_π and γ_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 8 *Monotonic convergence obtains up to a frontier of interest-rate rule coefficients given by the following condition:*

$$(a - 1) < \Upsilon_3\gamma_\pi + [1 - \rho' - \alpha'(1 - a)]\gamma_y - (1 - a)\gamma_i < 0 \quad (3.18)$$

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 3.4 contains the monotonic/oscillatory upper bounds of coefficients γ_π and γ_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 ξ and of the rigidity parameter κ the domain of coefficient γ_π 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 ξ and κ , 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 expectations¹⁴.

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 v . 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. 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 κ and ξ 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 3.3. 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 3.4-3.5: 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 3.6 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 3.2), 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

¹⁴This is exactly the opposite of what we observed in the case of optimal rule (see Table 3.3), where the upper bound of the inflation coefficient γ_π increased with an increase of both ξ and κ .

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 3.4) 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 the 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 γ_π - and sticky-prices/sticky-expectations - i.e, small κ and small ξ - may determine and extremely slow, if not flat, adjustment path of the economy toward the steady-state. As an example, look at simulation in Figure 3.7 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 inflation¹⁵ 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 κ is low as can be seen from estimates in Table 3.1. 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 advocated¹⁶.

As shown by Table 3.5, 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 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 3.8):

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.

3.4 Conclusions

Let me briefly summarize the main finding of this chapter. 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

¹⁵The flattening of the Phillips curve - i.e. a fall in our parameter κ - 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 κ parameter.

Weight of short-term rational expectations	Sticky-price parametrization $\kappa=0.1$	Intermediate-case parametrization $\kappa=0.4$	Flex-price parametrization $\kappa=0.7$
$\xi=0$	$\gamma\gamma<0.6$	$\gamma\gamma<0.6$	$\gamma\gamma<0.6$
$\xi=0.5$	$\gamma\gamma<0.6$	$\gamma\gamma<0.6$	$\gamma\gamma<0.6$
$\xi=0.9$	$\gamma\gamma<0.6$	$\gamma\gamma<1.1$ (oscillatory)	$\gamma\gamma<2.4$ (oscillatory)

Table 3.5 – Adaptive rule. Values of oscillatory and monotonic-stability upper bounds for γ_y assuming $\gamma_i = 0.5$ and $\gamma_\pi = 0$

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, 2006, 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 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 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 safer¹⁷.

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-invests, 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.

¹⁷The 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.

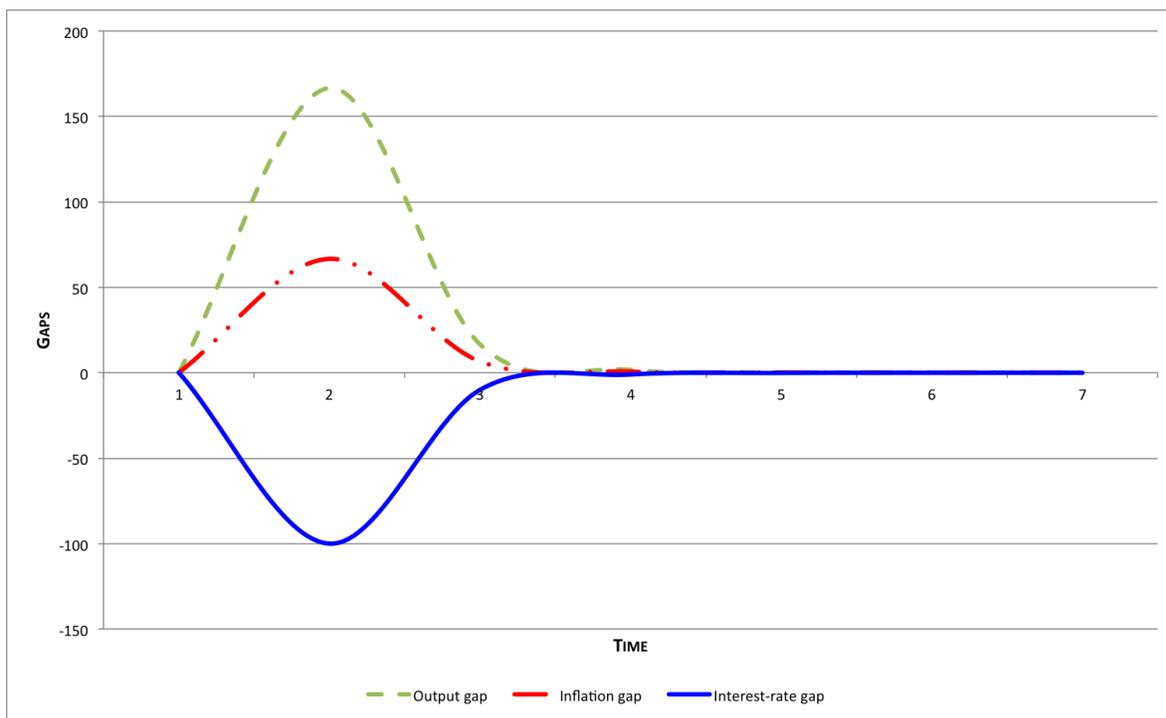


Figure 3.1 – Optimal rule, pure inflation targeting. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.1$ and $\xi = 0$

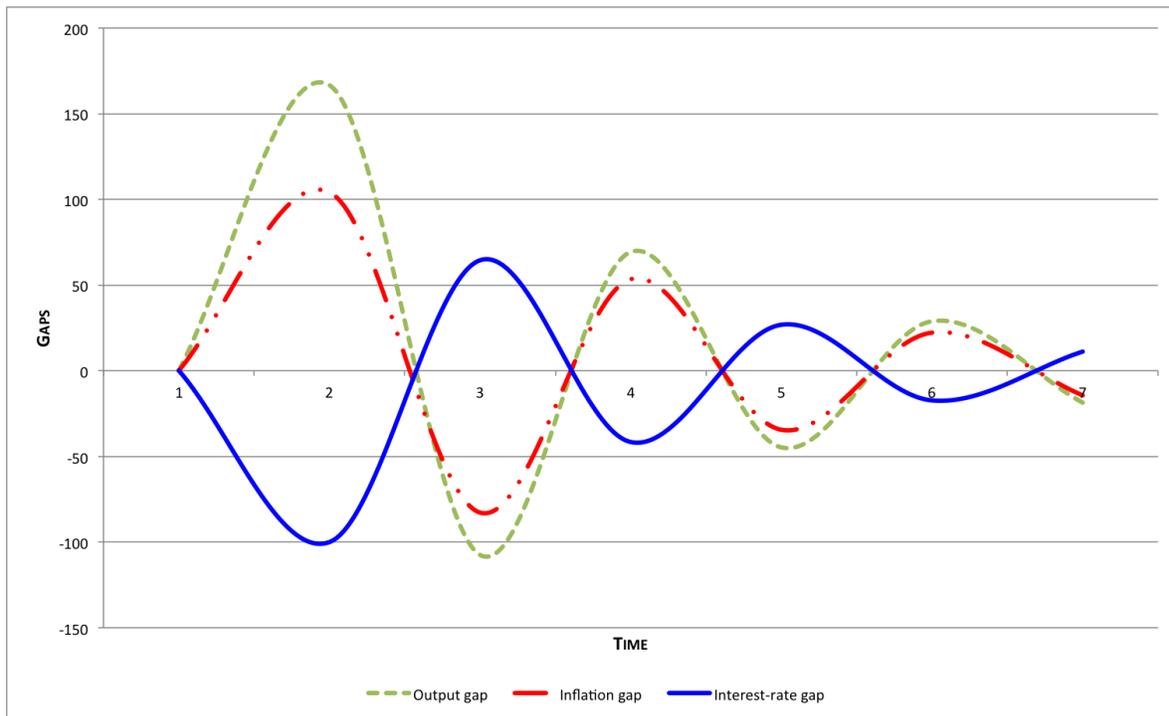


Figure 3.2 – Optimal rule, pure inflation targeting. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.4$ and $\xi = 0.5$

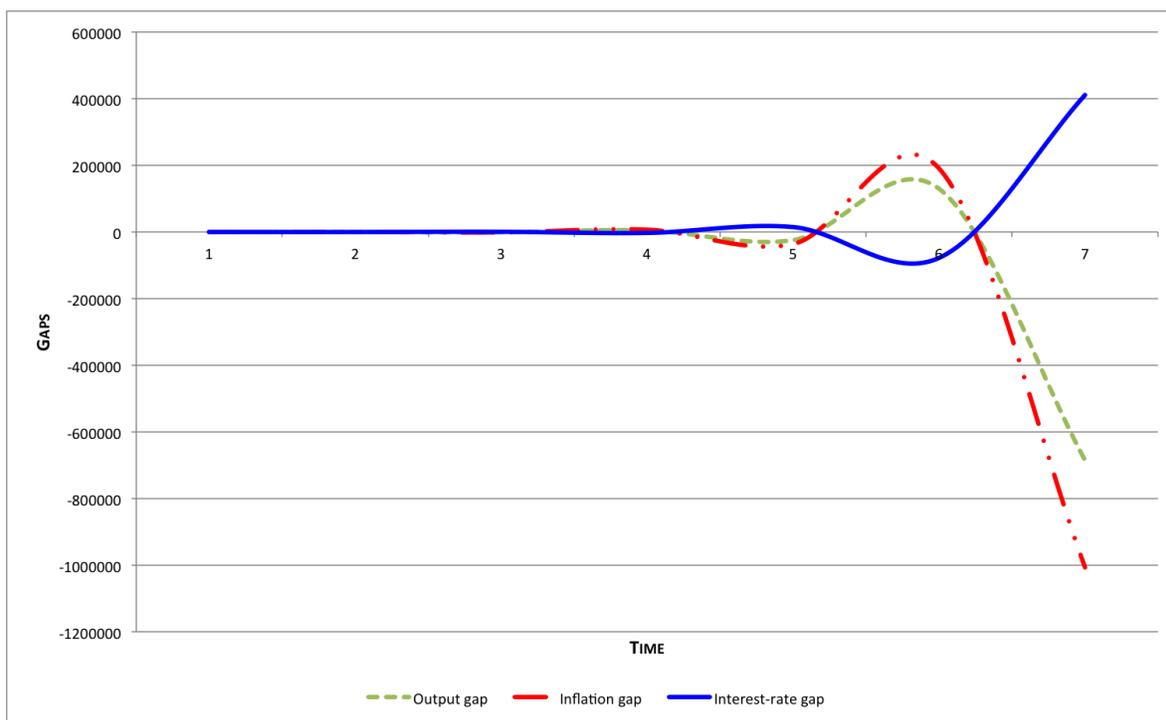


Figure 3.3 – Optimal rule, pure inflation targeting. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.7$ and $\xi = 0.9$

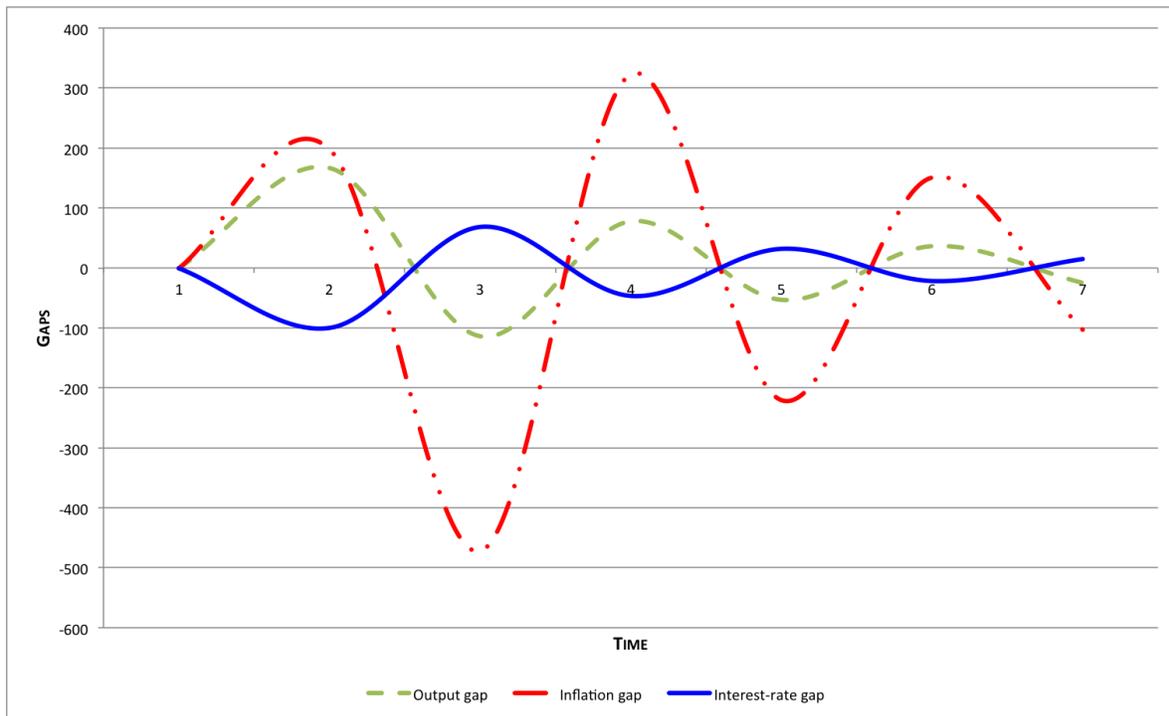


Figure 3.4 – Adaptive rule, pure inflation targeting. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.7$ and $\xi = 0.9$ - Oscillatory convergence

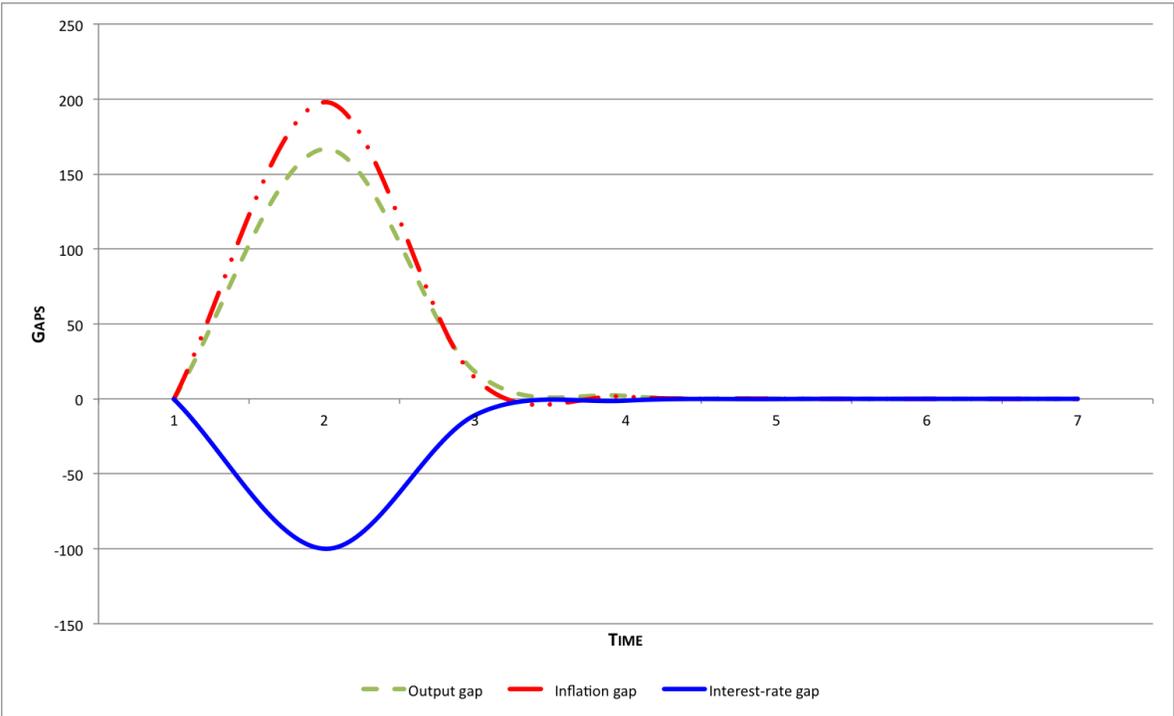


Figure 3.5 – Adaptive rule, pure inflation targeting. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.7$ and $\xi = 0.9$ - Monotonic convergence

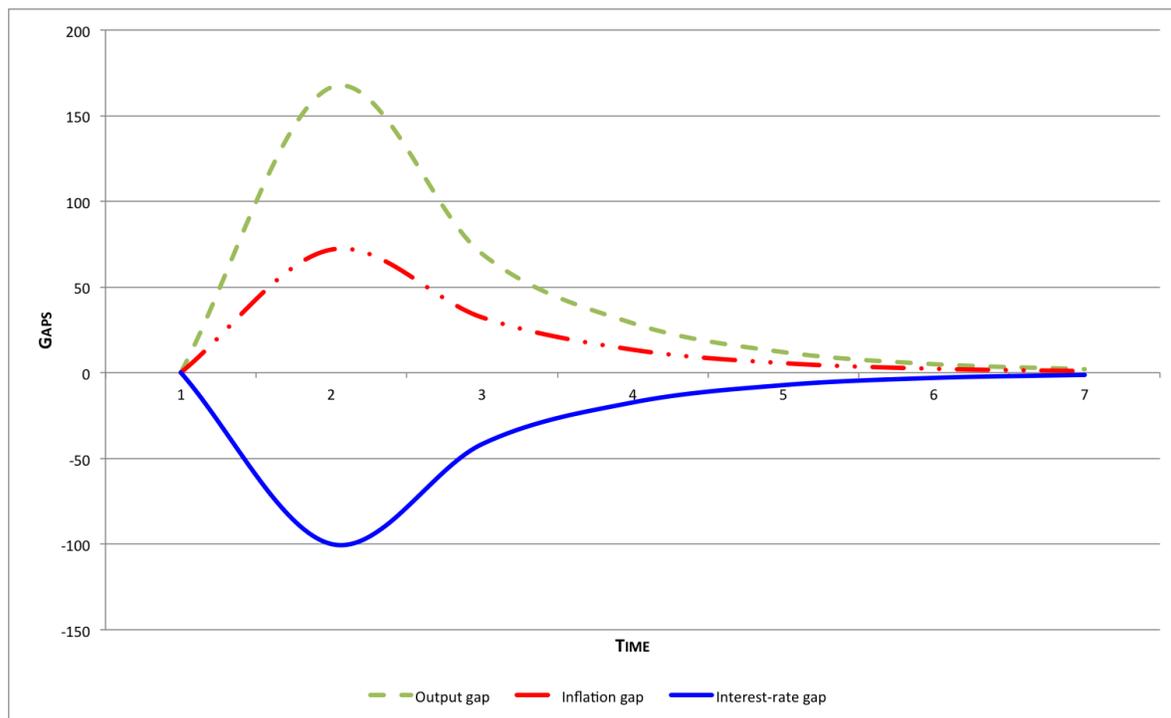


Figure 3.6 – Adaptive rule, pure inflation targeting. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.4$ and $\xi = 0.5$

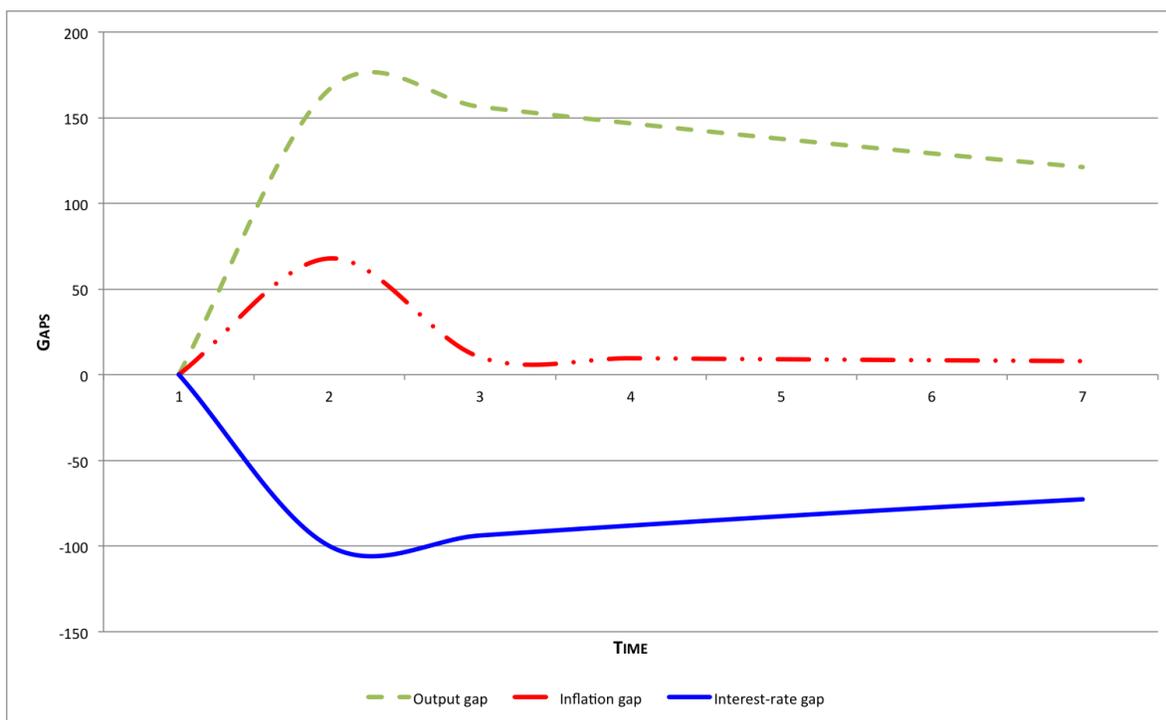


Figure 3.7 – Adaptive rule. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.1$ and $\xi = 0.5$ and empirical interest-rate coefficients $\gamma_i = 0.5$, $\gamma_\pi = 1.5$ and $\gamma_y = 0.5$

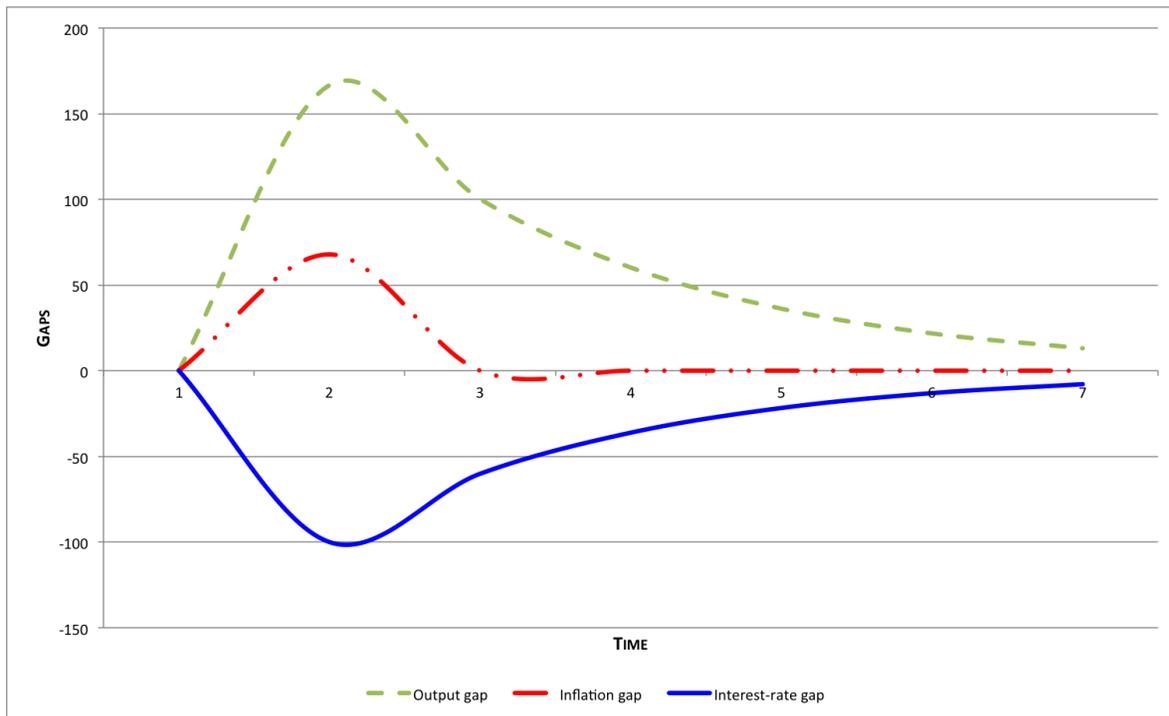


Figure 3.8 – Adaptive rule. Simulation of an initial interest-rate gap of -100 basis point with $\kappa = 0.1$ and $\xi = 0.5$ and empirical interest-rate coefficients $\gamma_i = 0.5$, $\gamma_\pi = 0$ and $\gamma_y = 0.5$

Chapter 4

Monetary Policy when the Natural Rate of Interest is unknown: the Fed and the Great Deviation

4.1 Introduction

One eternal question in monetary economics has been how the monetary authority should formulate and implement policy decisions so as to best foster ultimate policy objectives such as price stability and full employment over time. It is widely accepted that well designed monetary policy can counteract macroeconomic disturbances and dampen cyclical fluctuations in prices and output, thereby improving overall economic stability and welfare. The *rules-versus-discretion* debate concerns whether monetary policy should be conducted by rules known in advance to all or by policymaker discretion. For many years, the case for a monetary rule was associated with a particular proposal by Friedman (1959). Building on a tradition initiated by Simons (1936), Friedman introduced the idea that the effects of monetary policy were uncertain, occurring with long and variable lags. Therefore he argued that discretion in the management of money supply in the face of such uncertainty actually amplified economic fluctuations. Hence, Friedman argued for a constant-money-growth rule.

The case for rules has changed fundamentally since an important paper by Kydland and Prescott (1977) in which they show that pre-commitment to a rule could have beneficial effects that discretionary policies cannot have. Indeed, by committing to follow a rule, policymakers can avoid the inefficiency associated with the time-inconsistency problem that arises when policy is formulated in a discretionary manner. By making

future policy decisions more predictable, rule-based policy facilitates forecasting by financial market participants, businesses and households, thereby reducing uncertainty.

Various proposal for monetary policy rules have been made over time, and a vast literature continues to examine the relative advantages and drawbacks of alternatives in theoretical and empirical terms. In the last two decades Taylor-type rules (Taylor, 1993; Orphanides, 2007) have become the standard by which monetary policy is introduced in macroeconomic and in small or large econometric models. They serve as a benchmark for policymakers in assessing the current stance of monetary policy and in determining a future policy path (Asso et al., 2007).

Nevertheless the argument of Kydland and Prescott trivialized an important concern of policy makers: how to account for uncertainty in the link between policy instruments and ultimate objectives. Once one allows for uncertainty, there is a potential role for flexibility to deal with variability in the links. To the extent that some variations are systematic and can in some way be predicted, it is possible to incorporate feedback into a rule. However, some contingencies cannot be foreseen. When such events are potentially destabilizing, discretion may not be ruled out a priori. The previous Chairman of the Federal Reserve Bank of United States (Fed) regarded as a substantial degree of discretion as desirable so as to respond to shocks that were “*outside our previous experience, policy rules might not always be preferable*” (Greenspan, 1997). He claimed that “*simple rules will be inadequate as either descriptions for policy*” and he explicitly said that “*the economic world in which we function is best described by a structure whose parameters are continuously changing. The channels of monetary policy, consequently, are changing in tandem. An ongoing challenge for the Federal Reserve [...] is to operate in a way that does not depend on fixed economic structure based on historically average coefficients*” (Greenspan, 2004, p. 38).

The debate between rules and discretion came back in fashion with the arrival of the crisis of 2008. The discussion has not focused only unconventional decisions taken when the crisis had already begun, but also to analyze the possible effects that the monetary policies of the Fed has had in causing the crisis. The widespread assumption is that too low short-term nominal interest rates have led financial institutions to raise leverage and have provided investors with incentives to hold riskier assets, including structured products, which have promised higher returns at supposedly little extra risk (Rajan, 2005). Taylor (2007), using his original rule as a benchmark, argues that the federal funds rate was as much as three percentage points below the implied Taylor rule rate, causing the housing bubble, the financial crisis and the Great Recession. He calls

this experience the *Great Deviation* (Taylor, 2010).

While most subsequent commentary has agreed with Taylor's conclusion (Lombardi and Sgherri, 2007), the agreement has not been universal. Others have asserted that policy was appropriate for the macroeconomic conditions that prevailed, and that it was neither a principal cause of the housing bubble nor the right tool for controlling the increase in house prices. Bernanke (2010) argued that the systematic deviation largely disappears when real-time output gap estimates and inflation forecasts are used in the construction of the Taylor-rule benchmark. Specifically, Bernanke argued that the Fed policy closely followed a Taylor rule if forecasted, rather than realized, inflation is used. In fact, since monetary policy works with a lag, effective decisions must take into account the forecast values of the goal variables. Therefore, if one takes into account that policymakers should respond differently to temporary and longer-lasting changes in inflation, monetary policy after 2001 appears to have been reasonably appropriate, at least in relation to a simple rule. The deviation denounced by Taylor and others, that has been identified ex-post, would therefore reflect real-time measurement problems with the Taylor rule's input variables rather than a change in the monetary policy regime.

The debate on the use of different measures of inflation and output gap has unfortunately obscured a serious monetary policy analysis of the period 2002-2006. Almost no attention has been devoted to the role played by another key variable of the Taylor rule, namely the natural rate of interest. This lack of analysis is quite amazing since the natural rate of interest is a central concept in the current monetary policy literature (Woodford, 2003). The indictment that monetary policy has been systematically too accommodative¹ over the past decade from the perspective of the Taylor rule would be explained if the market rate of interest were lower than the natural rate. This phenomenon would occur despite the presence of a downward trend of the natural rate.

There are a number of factors that might have pushed down the natural rate over this period. Someone call into question the policy of low short-term interest rates practiced by the Fed in those years. Others speculate that low long-run real rates may in part reflect secular demographic trends, specifically the influence of the baby boomer generation on the asset markets (Takats, 2010). Also, high saving rates and underdeveloped financial markets in emerging market economies may have given rise to global asset shortage that has lowered natural rate of interests worldwide (Caballero

¹It should however be stressed that on this point there is no general consensus. For example, Justiniano and Primiceri (2010) argue that monetary policy was not too loose in the 2002-2006 period.

et al., 2008). Another potential factor is a possible increase in the perceived riskiness of capital assets in the wake of the recurrent asset price booms and busts since the late 1990s. Such higher capital price risk could drive long-run risk-free real interest rate levels well below trend output growth.

However, the problem is not the natural interest rate that is too low, but the fact that it is an unobservable variable. No doubt the Fed has conducted a monetary policy by setting an interest rate that was systematically lower than the *ex-post* natural rate of interest. But the origin of this error is different from that traditionally presented in the literature. In this chapter we will show how this mistake, rather than caused by an incorrect application of the Taylor rule, seems to lie primarily in a systematic error of estimate of the natural rate. Since the natural rate is an integral part of the Taylor rule, the problem seems to lie not so much in the application of the rule, but in the rule itself. This element has undoubtedly played a role in driving monetary policy onto a wrong track. The absence of inflationary pressures that characterized the so-called Great Moderation² has finally prevented the central bank from realizing the error. Indeed, the central bank discovers whether its market rate is too low or too high with the price level starting to rise or fall, and it can then adjust its rate accordingly. A constant inflation rate gives no information about whether monetary policy is right or not. As we saw in Chapter 3, a wrong monetary policy allows the financial imbalances to grow for many years.

This chapter is organized as follows. In section [4.2] I present the Taylor rule and I deal its empirical problems highlighted both by the economic literature and by the Fed. The debate on the effective application of the Taylor rule from 2001 to 2005 is presented

²The popular explanation of this period of substantial price stability is the cheap Chinese imports. But, as Milton Friedman argued that inflation is always and everywhere a monetary phenomenon, we could say that also the *absence* of inflation is also a monetary phenomenon. As Leijonhufvud (2007) recently stated, it is mostly the willingness of a number of central banks to accumulate enormous dollar reserve which explains the absence of inflation: China takes reserves in dollars as a tonic for exports, Russia as a medicine against the Dutch disease, while a number of other are doing the same on the principle that a few million a day, keeps the IMF doctors away. This policies keep American import prices from rising, and competition from imports keeps American consumer prices in check. Another relevant factor is the positive association between favourable 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 supporting 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 Section [4.3]. Section [4.4] illustrates the difficulties faced by the Fed in implementing a monetary policy rule in the presence of imperfect information regarding the natural rate of interest. I will show that it was the error in the estimate of the natural rate made by the U.S. central bank - and not the abandonment of the Taylor rule - that determined the policy of low interest rates and thus the financial crisis. In Section [4.5] I introduce a monetary policy rule that is independent from unobservable variables and I show that, following this rule, the short-term interest rate would not deviate so much from the natural rate. Section [4.6] concludes.

4.2 Taylor rules in theory and practice

Taylor rules are simple monetary policy rules that prescribe how a central bank should adjust its interest rate policy instrument in a systematic manner in response to developments in inflation and macroeconomic activity. Taylor (1993) developed a “*hypothetical but representative policy rule*” where the nominal interest rate i_t should respond to divergences of actual inflation rates π_t from target inflation π^* and of actual output y_t from potential output y^* , namely:

$$i_t = r^* + \pi_t + \eta(\pi_t - \pi^*) + \sigma(y_t - y^*) \quad (4.1)$$

where r^* is the natural rate of interest whereas η and σ are the two policy parameters. After simple algebraic manipulations, it can be rewritten as:

$$i_t = \mu + \gamma_\pi \pi_t + \gamma_y \hat{y}_t \quad (4.2)$$

where $\mu = r^* - \eta\pi^*$, $\gamma_\pi = 1 + \eta$, $\sigma = \gamma_y$ and $\hat{y}_t = y_t - y^*$. Based on the data of the previous few years, Taylor calibrated the long run target for inflation and the two parameters that determine the responsiveness of the federal funds rate to the two gaps. Moreover the natural rate of interest was based on a longer history of actual rates of interest. Thus, by setting the inflation target and the natural rate of interest equal to two and the response parameter η and σ equal to one half, he arrived at what is known as the classic Taylor rule:

$$i_t = 1 + 1.5\pi_t + 0.5\hat{y}_t \quad (4.3)$$

The positive econometric evaluations and its usefulness for understanding historical monetary policy generated a growing interest and almost all central banks began to

monitor this policy rule or related variants to provide guidance in policy decisions. Furthermore, by linking interest rate decisions to inflation and economic activity, Taylor rules greatly influenced also monetary policy research and teaching (Woodford, 2003; Clarida et al., 1999). As Clarida et al. (1999) emphasized, the rule is consistent with the main principles of optimal policy, that is a) it has the nominal rate to adjust more than one-to-one with inflation rate, b) real rates adjust to drive inflation back to target and, finally, c) the rule calls for countercyclical response to demand shocks and accommodation of shocks to potential GDP that do not affect the output gap.

Despite the Fed announced in February 1987 that it would no longer set M1 targets and despite Chairman Greenspan testified before the Congress that starting from July 1993 the central bank would downgrade the use of M2 as a reliable indicator of financial condition in the economy, it was only by 1995 that the Federal Open Market Committee (FOMC) begun regularly consulting the Taylor rule for guidance in setting monetary policy. During the meeting of the FOMC in January of that year Janet Yellen said that “[...] *it seems that a reaction function in which the real funds rate changes by roughly equal amounts in response to deviation of inflation from a target of 2 percent and to deviations of actual from potential output describes reasonably well what this committee has done since 1986. If we wanted a rule I think the Greenspan Fed has done very well following such a rule, and I think that is what sensible central banks do*”. A review of the transcript of meetings from 1993 to 2001 shows that the FOMC used the Taylor rule very much in the way recommended by Taylor in 1993. Not only did the staff prepare a range of estimates of the current stance of policy and the future policy path based on various policy rules, but members of the FOMC also regularly referred to rules in their deliberations.

A crucial element for the design and operational implementation of a Taylor rule is the detailed description of inputs. As McCallum (1993) pointed out, Taylor’s formulation was not “operational”. It required information that the policymaker did not necessarily have at his disposal. In particular it requires specificity regarding the measures of inflation and economic activity that the policy rule should respond to. The choice of the source of information and the type of updating processes regarding the unobservable concepts are essential for practical analysis because there is often a multitude of competing alternatives and a lack of consensus about the appropriate concepts and sources of information that should be used for policy analysis.

This situation is particularly complex in regard to the treatment of unobservable concepts such as the output gap or the natural rate of interest. Econometric evaluations

suggest that inferences regarding the performance of the Taylor rule often depend sensitively on assumptions regarding the availability and reliability of these two inputs. Real time estimates of potential output can be derived in a number of ways (Hauptmeier et al., 2009) and - as shown by Orphanides and Williams (2002a) - they are subject to large and persistent errors. Taylor in his original paper proposed the computation of potential output by putting a time trend to real GDP. McCallum and Nelson (1999) and Woodford (2001) dissent with the use of time trends as estimates of potential output for two main reasons: first, the resulting output gap estimates might be overly sensitive to the chosen sample; second, de-trending ignores the potential impact of permanent shocks on output (Siklos and Wohar, 2004). Clarida et al. (2000) measured potential output using the Congressional Budget Office's (CBO) estimates and by fitting a segmented trend and quadratic trend to real GDP. Many papers estimate potential output by applying Hodrick-Prescott filter whereas quite few use band-pass filter.

A similar problem arises with the natural rate of interest. It varies over time because it depends on factors such as the growth rate of potential output, fiscal policy and the willingness of savers to supply credit to households and businesses. As well as for the potential output, the estimation of the natural rate is not straightforward and is associated with a very high degree of uncertainty. Furthermore there is not a consensus on the estimation technique and on the determinant of this rate. We can distinguish at least three different types of estimation technique. The simplest approach is to assume that the natural rate of interest is equivalent to the trend real rate of interest (Basdevant et al., 2004; Caresma et al., 2005; Larsen and McKeown, 2004). This approach is closer to a pure statistical measure and may be reasonable over short periods, when inflation and output growth are stable, but leads to substantial biases when output or inflation vary significantly. A more robust approach is to combine statistical tools with structural macroeconomic modeling techniques, taking into account also the evolution of real fundamentals such as determinants of trend GDP growth and preferences (Giammarioli and Valla, 2003; Mésonnier and Renne, 2004; Neiss and Nelson, 2001; Sevillano and Simon, 2004). Unfortunately the econometric results obtained with these specifications are not very precise. There are at least three major kinds of difficulties that can bias the estimates. First, the general theory of statistic tells us that, in estimating unobservable variables, the more observations that are used, the more accurate the estimates will be. However we can observe the data only up to today. Thus the estimate of the natural rate of interest based on data that are available today - i.e. the so called *one-sided estimate* - will be different from the estimate we will make when we have data beyond

today - i.e. the so called *two-sided estimate* - because the latter will take into account future data over next periods. The discrepancy between the *one-sided* and the *two-sided* could be as large as one to two percentage points. Second, macroeconomic data are often revised, and sometimes the revision can be quite substantial. Such revisions will bias the estimates of both the parameters of the model and the natural rate of interest. Of course, the magnitude of the biases will depend on the size of the data revisions. As pointed out by Clark and Kozicki (2005) these mistakes could be as high as one to two percentage points. Third, different model specifications can generate very different estimates of the natural rate of interest. Clark and Kozicki (2005) find that estimates of the natural rate are sensitive to model specification and that these differences can be as large as one to two percentage points.

Finally, a last estimation method extracts the natural rate of interest from the financial market indicators (ECB, 2004) or from a money demand function which depends on the expected natural rate of interest (Andres et al., 2009). Comparing these three methods, Caresma et al. (2005) conclude that the differences in levels and volatility are big enough to take the results with caution. As has been shown by Kozicki (1999), Taylor's proposed target interest rate is not robust to different measure of potential output and natural rate of interest³. If policymakers rely on flawed estimates, they will encounter persistent problems in achieving their inflation and/or full employment objectives and they may seriously destabilize the system (Primiceri, 2006; Tamborini, 2010b).

These and other problems were already clear from the adoption of the Taylor rule as a policy benchmark. This is proved by the fact that at the November 1995 FOMC meeting, the board of the Fed started to discuss several critical elements which have become items of discussion even in academia. First, it was noted that Taylor prescribed policy interest rate responding to the inflation rate and output gap that correspond to the same quarter in which policy decision were made. Contemporaneous setting requires the central bank to know the current quarter values of real GDP and the price index when setting the federal funds rates for the quarter. But in practice the Fed gets provisional data on real GDP one month after the end of the quarter and final data after three months. Moreover, since monetary policy works with lags, effective monetary policy must take into account the forecast values of the goal variables, rather than the

³In his paper Kozicki (1999) uses the Taylor rule to calculate interest rate recommendations that would result from alternative measures of inflation and output. Differences in interest rate settings range from a minimum of 0.6 percentage points to a maximum of 3.8 percentage points.

current values (Clarida et al., 1999; Svensson, 2003; Orphanides and Wieland, 2008). However, it should be pointed out that some years later Rudebusch and Svensson (1999) and Orphanides and Williams (2006) do not find a significant benefit from responding to expectations out further than one year for inflation or beyond current quarter for output gap. Rules that respond to inflation forecasts further into the future tend to generate indeterminacy in rational expectations model (Taylor and Williams, 2010).

Second, the equal weight on inflation and output gap in the Taylor rule may be appropriate only in the case of supply-side shocks, whereas in case of demand shocks a greater weight to the output gap may be better suited. Usually all the analyses are conducted using an output gap coefficient between 0.5 and 1.0. The rationale is usually based on estimates of past behavior of the Fed, but also it is claimed that a larger coefficient is optimal in the context of DSGE models.

Third, the federal funds rate prescribed by the Taylor rule is highly sensitive to how inflation is measured. As seen above for the output gap, also different measures of the rate of change of prices can diverge significantly for long stretches, potentially providing different signals for the appropriate course of monetary policy. While in the Carnegie Rochester paper, Taylor (1993) used the price index given by the GDP price deflator, subsequent research has used other measures like Consumer Price Index (CPI), core CPI inflation, CPI less food and energy and the Personal Consumption Expenditure (PCE) deflator. Even when a particular index is chosen, there are more choices to make, i.e. annual or quarterly. Even though the differences between these various measure could be minimal especially in the case of low and stable inflation, some authors experimented the rule with variety of inflation measures and show a substantial variation in estimated policy parameters (Carare and Tchaidze, 2004).

Fourth, it is desirable to adopt a version of the Taylor rule that allows gradual adjustment in the natural rate of interest (Woodford, 2003). Thus, a more general version of the Taylor rule could be the following:

$$i = \lambda i_{t-1} + (1 - \lambda) [(r^* + \pi_t) + \eta(\pi_t - \pi^*) + \sigma(y_t - y^*)] \quad (4.4)$$

where λ represents the degree of inertia. The equation can be rewritten as:

$$i = \lambda i_{t-1} + (1 - \lambda) [\mu + \gamma_\pi \pi_t + \gamma_y \hat{y}_t] \quad (4.5)$$

Several arguments have been put forth in favor of interest rate smoothing. In par-

ticular, the Fed would want to avoid frequent reversals in the direction of interest rate movements. These reversals may appear as mistakes to the public, thus maintaining momentum in interest rate movements will keep confidence in the central bank. Moreover, interest rate smoothing may also be a response to the unavailability of accurate economic information and the uncertainty associated with the monetary transmission mechanism. Sack and Wieland (2000) question whether interest rate smoothing is deliberate or simply the result of monetary policy reacting to persistent macroeconomic conditions. If interest rate smoothing reflects the reaction of monetary authorities to persistent macroeconomic variables, one would expect the coefficient on the lagged interest rate to be small or insignificant. However empirical estimates of the Taylor rules find high and significant inertia (Goodhart, 1999; Rudebush, 2002; Dueker and Rasche, 2004), indicating that interest rate smoothing is deliberate.

4.3 Taylor rule and monetary policy after 2001

Monetary policy after 2001 has been subject to much controversy. The end of the *dot-com* boom and the consequent sharp decline in stock prices caused a moderate recession of the US economy between March and November. The terrorist attacks of September 11, 2001 and the invasion of Iraq in March 2003, as well as a series of corporate scandals in 2002, further clouded the economic situation in the early part of the decade. From 2000 onwards the target federal funds rate was lowered quickly in response to the 2001 recession, from 6.5% in late 2000 to 1% in June 2003 and then remained at that level for a year. In June 2004 the Fed began to raise the target rate, reaching 5.25% in June 2006 before pausing⁴. The expansionary monetary policy of 2002 and 2003 was motivated by two main factors. First, after the recession of 2001 the GDP, which normally grows above trends in the early stages of an economic expansion, rose at an average rate of 2% in 2002 and in the first two semesters of 2003. This rate was not sufficient to affect the unemployment rate, which continued to stay above 6%. The slow recovery could be interpreted as reflecting a “capital overhang” left over from the rapid pace of investment in ITC during the boom of the late 1990s that limited both new capital investment and the need for employers to add new workers. The second factor

⁴In the same period the Fed accompanied the low policy rates with many statements about its intention in the subsequent periods. For example, in August 2003 the Fed announced that the policy was likely to remain accommodative for a “considerable period” whereas in May 2004, a month before the increase of the target rate, the Fed suggested that the long phase of expansionary policy was close to conclusion (FOMC, August 2003; FOMC, January 2004).

which justifies the expansionary monetary policy was the concern about the possibility that US could experience an unwelcome decline in inflation as in Japan. The risk of approaching the zero lower bound has pushed the Fed to lower the interest rate in advance to avoid a situation in which monetary policy was ineffective (Reifschneider and Williams, 2000; Ahearne et al., 2002).

Although macroeconomic conditions certainly warranted accommodative policies in 2001 onwards, the question remains whether policy was more expansive than necessary. Taylor (2007) argued that the federal funds rate fell below the prescribed Taylor rule rate from mid-2002 to mid-2006 and he identified precisely in this deviation - which was as large as three percentage points for a considerable period - the cause of the housing price bubble, the build-up of financial imbalances and thus of the Great Recession (Taylor, 2010; 2011). Taylor argued that this deviation reflects clearly a change in the policy regime. However, this conjecture is rejected by Bernanke (2010). He criticized Taylor on the fact that he used realized rather than forecasted inflation. He showed that using *forecast* instead of *realized* CPI the gap between the actual and prescribed interest rates narrowed considerably.

Nevertheless, if we analyze in detail Bernanke's answer, we note that it is unable to respond appropriately to criticisms made by Taylor. Figure 4.3 and Figure 4.4 plot the implied federal funds rate with the realized CPI inflation and with the forecast one-year-ahead CPI inflation. It is simple to note that the results are very similar. When the output gap is set $\gamma_y = 0.5$, the federal funds rate is below the prescribed Taylor rule rate throughout the considered period. On the contrary, if $\gamma_y = 1.0$ the difference is not so large, but the federal funds rate is below the prescribed Taylor rule in all but two quarters from 2002:Q2 to 2005:Q3.

Perhaps to better explain the discrepancy between the statements of Taylor and those of Bernanke there is something else. Actually a better analysis could be obtained by changing the inflation indicator. As we mentioned before, the economic literature has never been particularly careful to define precisely which inflation variable would be better to use in the Taylor rules. Indeed, when we come to policy prescriptions, it is not clear what particular measure should be used. Kohn (2007) argued that the Fed policy closely followed a Taylor rule if the core Personal Consumption Expenditure (PCE) deflator, rather than the CPI, is used to measure inflation.

Let us do a simple numerical analysis of these statements. Data on nominal GDP and thus on inflation measured by the GDP deflator were published by the Fed of Philadelphia web site. One-to-four quarter ahead internal Fed inflation forecasts are

available on the Greenbook. Although the forecasts are not publicly available after 2005, there is a close enough fit between Greenbook and Survey of Professional Forecasters (SPF) forecasts so that the data can be spliced together. Other real time inflation measures are the CPI and the core PCE deflator. The data on the Fed funds rate are freely available and we use the (annualized) quarterly effective rate published by the Federal Reserve Board. The real-time output gaps are available only until the end of 2005, but the Congressional Budget Office (CBO) publishes real-time potential GDP estimates that can be combined with real-time output gap. Following Poole (2007) I construct the missing output gaps by using actual and potential GDP estimates for the previous quarter.

With these data I was able to reconstruct a reliable database. Figure 4.5 illustrates the prescribed interest rate with inflation measured by the realized core PCE deflator, the output gap from the Greenbook until 2004:Q4 and the CBO thereafter, and an output gap coefficient of 0.5. While the actual federal funds rate is below the prescribed Taylor rule rate from 2002 to 2005, the gap is much narrower than with headline CPI inflation, typically around one rather than three percentage points. An even closer fit can be found using core PCE inflation and an output gap coefficient of 1.0 where, with only minor deviations, the prescribed and actual rates nearly coincide from 2001:Q2 to 2004:Q4.

Another piece of evidence that the prescribed interest rate depends more on the use of PCE instead of CPI inflation than on the use of forecast instead of realized inflation is provided by Figure 4.6, which is identical to Figure 4.5 except that realized core PCE inflation is replaced by forecast PCE inflation⁵. With an output gap coefficient of 0.5, the gap between the prescribed and actual rates is narrow and, with a coefficient of 1.0, the prescribed and actual rates are very close between 2002:Q1 and 2004:Q4.

This evidence leads us to conclude that the prosecution of Taylor that the Fed would implement a less rule-based monetary policy is not particularly robust. At least until 2005, the U.S. central bank does not seem to have deviated very much from the practice of the previous decades and from the recommendations of most macroeconomic theory and models. The debate between Taylor and Bernanke seems to be the result of theoretical and empirical misunderstandings relating to the choice of the indicators of inflation and output that accompany the implementation of monetary policy rules in the last twenty years. But if the “Great Deviation” mentioned by Taylor does not

⁵The inflation forecasts are from Orphanides and Wieland (2008) through 2006:Q4 and from the SPF thereafter.

seem to be reflected in the data, there is another “Great Deviation” that received less attention and that we will try to analyze in the next section.

4.4 The Fed and the Natural Rate of Interest: the authentic Great Deviation

If the comparison made in the previous section may help to clarify whether the Fed followed the *original* Taylor rule, it does not allow us to clarify if the Fed’s monetary policy was actually too expansive or not. In order to evaluate the stance of monetary policy we should investigate the gap between the market real rate of interest and the natural rate. Despite being a fundamental concept in both traditional monetary theory and in its most recent advances (Woodford, 2003; Trautwein and Zouache, 2009), it is still not clear what the natural rate of interest really is and what is meant with this variable. For the Classics, the natural rate was the real rate that equated savings and investment. Further, this rate also stabilized the general price level and should be equal to the marginal product of capital. But as Amato (2005) points out, even Knut Wicksell defined the natural real interest rate in at least three different ways: the marginal productivity of capital, the interest rate that equates saving and investment, and the interest rate consistent with price stability. Of course, this does not necessarily imply that those definition are inconsistent with each other, but there is no reason to draw an equality sign between these objects, so that they should be treated as three different natural rates definitions (Laidler, 1991, p.130). On the other hand, today’s definitions differ from those described above. In micro-based models the natural rate is defined as the flexible price equilibrium level of the real rate. According to another popular definition, the natural rate is equal to the real rate that stabilizes inflation, i.e. the so-called Non-Accelerating Inflation Rate of Interest (NAIRI).

With regard to the Fed, even if there is no single definition of the natural rate of interest, there is clearly a common view of this concept. Roger W. Ferguson Jr., a former Vice Chairman of the Board of Governors of the Fed system, defined the natural rate of interest⁶ as “*the level of the real federal funds rate that, if allowed*

⁶The concepts “neutral real interest rate”, “natural real interest rate” and “equilibrium real rate” are sometimes used interchangeably in the literature and also during the FOMC. They do differ, however. The natural rate is the rate of interest at which investment and savings are equal, whereas the neutral rate is that at which there are no evident inflationary pressure (Amato, 2005). Curiously, the only one to justify in some way the use of one of these terms is Ferguson, who admits to prefer the last one because “*by using the word equilibrium it reminds us that it is a concept related to the*

to prevail for several years, would place economic activity as its potential and keep inflation low and stable” (Ferguson, 2004, p. 2). On the other hand Janet Yellen, the current Vice Chairman of the Fed, states that “[...] policy can be deemed natural when the federal funds rate reaches a level consistent with full employment of labor and capital resources over the medium run”. This is a definition that is very similar to that give by Alan Greenspan. Indeed in his Humphrey Hawkins testimony to Congress in May 1993, Greenspan stated that the equilibrium interest rate is “[...] the real rate level that, if maintained, would keep the economy at its production potential over time. Rates persisting above that level, history tells us, tend to be associated with slack, disinflation, and economic stagnation”. On the contrary rates below that level are associated “[...] with eventual resource bottlenecks and rising inflation, which ultimately engenders economic contraction. Maintaining the real rate around its equilibrium level should have a stabilizing effect on the economy, directing production toward its long-term potential” (Greenspan, 1993).

It is also clear that the Fed sees the natural rate of interest as a variable that can change over time. For this reason there is not much confidence in the literature that derives the natural rate by taking averages of the actual real rate observed over long period of times. An estimate derived from long-run observations may not be relevant to policy for two main reasons. First, economic conditions during the policy-relevant period might differ from the average conditions during the observation period. Second, the economy changes in ways that tend to limit the relevance of historical observation for policymaking. Indeed “the value of the natural rate depends on the strength of spending - that is, the aggregate demand for US produced goods and services. Aggregate demand, in turn, depends on a number of factors. These include fiscal policy, the pace of growth in our main trading partners, movements in asset prices, such as stocks and housing, that influence the propensity of households to save and spend, the slope of the yield curve, which determines the level of the long-term interest rates associated with any given value of the federal funds rate and the pace of technological change, which influences spending” (Yellen, 2005). Thus, all the estimations of the level of the natural rate can widely depend on the type of measure and the prevailing and projected economic conditions. In other words, for the Fed the natural rate of interest is a forward-looking notion and all the variables that contribute to build a macroeconomic forecast are relevant to estimate it.

clearing of the markets” (Ferguson, 2004, p.2).

In the late Nineties, as evidence mounted that trend productivity growth had increased, the issue of the natural rate of interest became even more important⁷. All the member of the Board were concerned that maintaining Taylor's fixed 2% natural rate would lead to an overly stimulative policy. In particular, the previous President of the Federal Reserve of Richmond Alfred Broaddus said that "*an increase in trend productivity growth means that the real short rate need to rise. [...] The reason is that households and business would want to borrow against their perception of higher future income now in order to increase current consumption and investment before it's actually available. The Taylor rule does not give any attention to that kind of real business cycle reason for a move in rates*" (FOMC, June 1999, pp. 99-100).

Quantitative measures of the equilibrium real rate of interest are a regular input in the monetary policy debate at the Federal Reserve, as demonstrated by the fact that a chart with a range of estimates of it is included in most published Bluebooks at least since May 2001. These estimates are given by the use of model FRB/U.S. model - i.e., the staff's large-scale econometric model of the U.S. economy - and the predictions about the equilibrium rate depend on a very broad array of economic factors, some of which take the form of projected values of the model's exogenous variables. In order to understand if the Fed really used these estimates in defining its monetary policy, let us embed these measures of the natural rate, which we denote by \hat{r}_t^* , in a class of policy rules of the form:

$$\tilde{i}_t = \hat{r}_t^* + \pi_t + \eta(\pi_t - \pi^*) + \sigma(y_t - y^*) \quad (4.6)$$

and let us set the two policy coefficient at $\eta = \sigma = 0.5$ as suggested by Taylor. Figure 4.7 depicts the gap between the implied federal funds rate \tilde{i}_t - given \hat{r}_t^* - and the effective Fed funds rate i_t in the case of present and forecast CPI. In both cases, especially in the interval 2002:Q1-2006:Q2, the gap is always negative. In other words, the Fed seems to have *systematically* set an interest rate lower than what it should have done according to the Taylor rule, *given* the natural rate of interest estimated by itself. The statistical analysis of these *policy errors* - i.e., the difference between the effective rate i_t and the implied rate \tilde{i}_t - seems to confirm this impression⁸. Using the database presented in the previous section, we test the hypothesis that the error term ε_t is autocorrelated. The

⁷This may reflect also the very low U.S. private savings ratio, and the sharp surge in the U.S. government deficit and debt ratio.

⁸Note that, while maintaining both the policy coefficients and the variables unchanged, the gap between i_t and \tilde{i}_t is entirely due to an error in the estimate of the natural rate of interest by the Fed.

	Taylor coefficients	Higher output-coefficient
ϕ_1	0.625*** (0.216)	0.627** (0.224)
ϕ_0	-0,754* (0.427)	-0.596 (0.353)
Observations	17	17
R-squared	0.357	0.344
<i>Standard errors in parentheses</i>		
* p<0.01 ** p<0.05 *** p<0.1		

Table 4.1 – Errors with CPI inflation, Test of autocorrelation

equation that we estimate is thus a first-order autoregressive process AR(1)⁹:

$$\varepsilon_t = \phi_0 + \phi_1 \varepsilon_{t-1} + u_t \quad (4.7)$$

under the null hypothesis $H_0 : \phi_1 = 0$, namely there is no autocorrelation. From Table 4.1 it can be noticed that this hypothesis is rejected both in the case in which the monetary policy rule is based on the original parameters of Taylor and in the case in which the output-gap coefficient is fixed at a higher level ($\sigma = 0.75$). In the former case, estimation errors appear to move around a drift ϕ_0 that is slightly negative and statistically significant. Unfortunately we have too few observations to conduct a reliable test on the average of the errors. However, in the time-interval considered, the errors are all negative, therefore their average will definitely be different from zero¹⁰.

To explain the fact that the Fed has systematically fixed the short-term interest rate at a lower level than it should have done following the Taylor rule, some accusers focus on the role of a *discretionary* monetary policy. It is assumed that Alan Greenspan, setting low federal funds rate and through low-inflation expectations, has sought to directly influence the long-term interest rate. The central idea of this view is that Greenspan was convinced to be able to push down long-term interest rate not just by directly purchasing long-term securities - as Keynes argued in his *Treatise on Money* - but by creating expectations that future short-term interest rates will be low¹¹. The

⁹I also estimated the equation with two delays AR(2) - i.e. $\varepsilon_t = \phi_0 + \phi_1 \varepsilon_{t-1} + \phi_2 \varepsilon_{t-2} + u_t$ - but in both cases the coefficient ϕ_2 was not statistically significant.

¹⁰I conducted a Z-test on the mean, under the null hypothesis that it is equal to zero $H_0 : \mu_\varepsilon = 0$. Not surprisingly, in both cases this hypothesis is rejected.

¹¹This argument refers to the old debate about the so-called “Classical Dichotomy”, i.e. if the natural rate of interest is assumed to be independent of nominal phenomena including the money rate

unorthodox mistake would be that the natural rate is not influenced by monetary policy and that it was the short-term interest rate to have to adapt to the long-term one. We do not know whether this was really Greenspan's intention or not. Looking *ex-post* at what has happened over the period we are considering, it seems that this conjecture is not supported by the data. Indeed the long-term rate has not been closely correlated with the contemporaneous short-term policy rate. Time series of the short-term and the long-term rate have been shown to have quite different statistical properties, but there is of course some correlation. Between 1971 and 2002, the federal funds rate and the long-term rate moved in lockstep. The correlation between them was a tight 0.85 (Greenspan, 2009). Nevertheless the link between the two interest rates is unlikely to be constant. Rather, it seems to be time-variant. There have been many period when there has been no apparent relationship. Andrews (1993) showed that the relationship between Treasury yields and the funds rate changed in the late 1980s and diminished to insignificance between 2002 and 2005. During the monetary policy tightening of 2004-2005 the US government yield did not rise at all (Rosenburg, 2007): this was the famous *Greenspan conundrum*¹². Thornton (2012) says that the change in the relationship between the federal funds rate and the 10-year yields occurred when the FOMC began using the fund rate as a *policy* target rather than an *operating* target as it had previously done. The use of the federal funds rate as a policy instrument caused the funds rate to be determined by monetary policy consideration and not by economic fundamentals as before. The long-term interest rate was unaffected by this change and continued to be determined by economic fundamentals. This is an instance of the so-called Goodhart's Law, which states that any observed statistical regularity will tend to collapse once pressure is placed upon it for control purposes.

However, the debate about the responsibilities of the Fed is likely to overlook an important element. The hypothesis that the U.S. central bank has implemented a discretionary monetary policy seems not to have an empirical counterpart if we change the inflation indicator. Also in this case, if in equation (4.6) we use PCE deflator instead CPI inflation, the result would be very different (Figure 4.8). The effective federal funds rate follows more closely the implied rate, *given* the natural rate estimated by the Fed.

of interest or not. In this second case, the real economy would lack an anchor and would be affected by hysteresis and monetary policy would have permanent real implications via its influence on the natural rate of interest. In this context estimates of Taylor rules in which empirical proxies for the natural rate are assumed to be exogenous, would be misspecified (Clarida et al., 1999)

¹²For some critical remarks on the fact that the long-term rate had continued to fall even after the Fed had started to gradually increase the federal funds rate see Turner (2013).

	Taylor coefficients	Higher output-coefficient
ϕ_1	0.0625	0.365
	(0.258)	(0.218)
ϕ_0	-13.26	0,0130
	(12,75)	(0.111)
Observations	17	17
R-squared	0.004	0.157
<i>Standard errors in parentheses</i>		
* p<0.01 ** p<0.05 *** p<0.1		

Table 4.2 – Errors with PCE inflation, Test of autocorrelation

Setting the output-gap policy coefficient to 0.7 the performance improves further. The difference between the two curves is slight and random. If we replicate the same test we have done with equation (4.7), we obtain two important results summarized in Table 4.2. The first is that the parameters are not statistically significant and thus there seems to be no-autocorrelation between the errors¹³. The second is that, by conducting a Z-test on the mean of the errors, the null hypothesis $H_0 : \mu_\varepsilon = 0$ is not rejected. Therefore the gap between theoretical and observed interest-rate seem to be serially uncorrelated with zero-mean, i.e. the errors follow a *white noise* process.

Thus, the mistake made by the Fed is not a proper policy error. The U.S. central bank appears to have applied with sufficient diligence all the requirements of the Taylor rule, *given* its estimates of natural interest rate. The real problem is that the latter was wrong. Sadly, though, estimates of the natural rate are often very elusive and imprecise. Policy makers have repeatedly expressed their skepticism about the ability of obtaining precise estimates of the natural rate (Blinder, 1998; Ferguson, 2004). However, this variable is part of the Taylor rule and should be derived in some way.

Because of the difficulty associated with properly defining the natural rate of interest, the latter is often obtained by way of approximations of observable variables. A good proxy for the natural rate of interest is usually identified in the 10-year bond yield on risk-free assets (Beenstock and Ilek, 2010; Gerlach and Moretti, 2011). From 1980 to 2007 this variable has shown a downward trend (Figure 4.1). In particular, from that time forward, it has been low, well below its historical averages¹⁴. As Greenspan noted

¹³Also in this case I have estimated an AR(2) model and the result is that the coefficient ϕ_2 was not statistically significant.

¹⁴For a detailed survey of the literature on this point see Amato (2005).

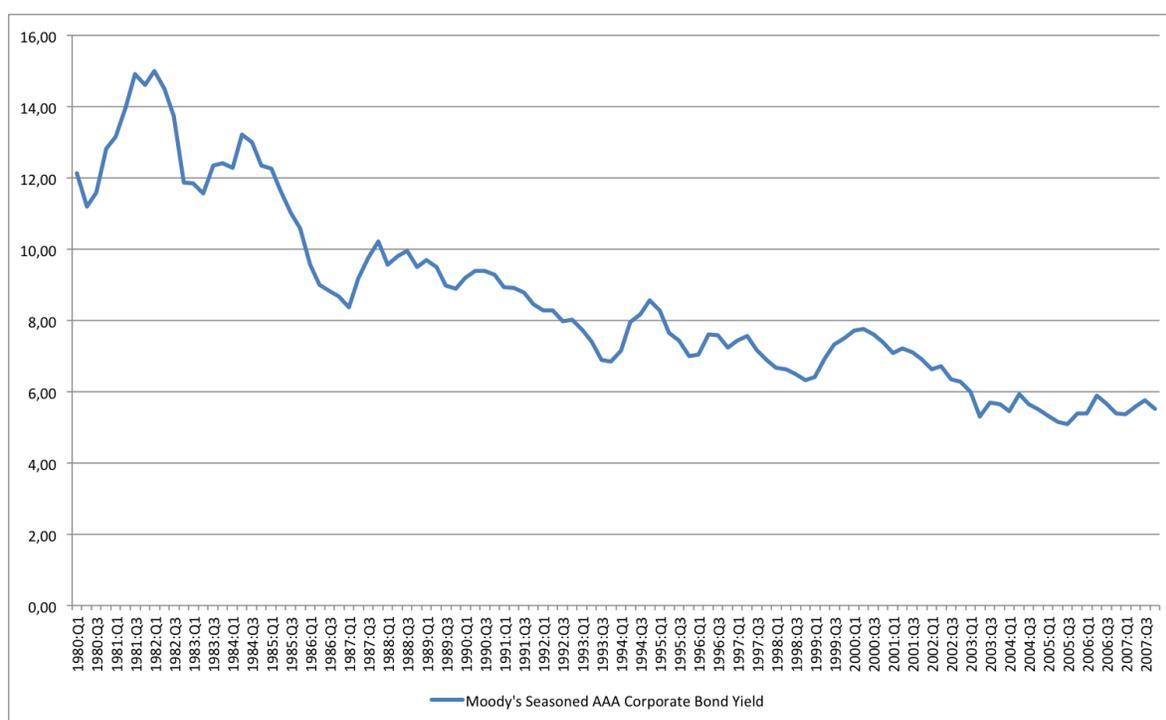


Figure 4.1 – Seasoned AAA Corporate Bond Yield

during his testimony before the Congress in July 2004, two distinct but overlapping developments appear to be at work in explaining the low level of long-term interest rate: a longer-term trend decline in bond yields and an acceleration of that trend over the period. This trend is perplexing on both macroeconomic and microeconomic grounds. The macroeconomic paradox is that the fall to a very low level in the past few years has occurred when the potential growth rate of the global economy has risen and when investment in the emerging economies has been strong, i.e. when theoretically the natural rate would have to increase. The microeconomic paradox is that the decline in the real rate has occurred even though the volatility of long-term rates has actually risen. This is the opposite of what one would expect, since normally investors would require some compensation for holding a more volatile asset (Watson, 1999).

This decline in the long-term interest rate can be ascribed to expectations of lower inflation and of a reduced risk premium resulting from less inflation volatility due to the substantially increased production capacity worldwide. In addition, Greenspan thought that the declining long-term yields reflected “*an excess of intended saving over intended investment*” (Greenspan, 2005b). On this point the most widely accepted explanation of low-term rates is the Bernanke’s thesis of the global “saving

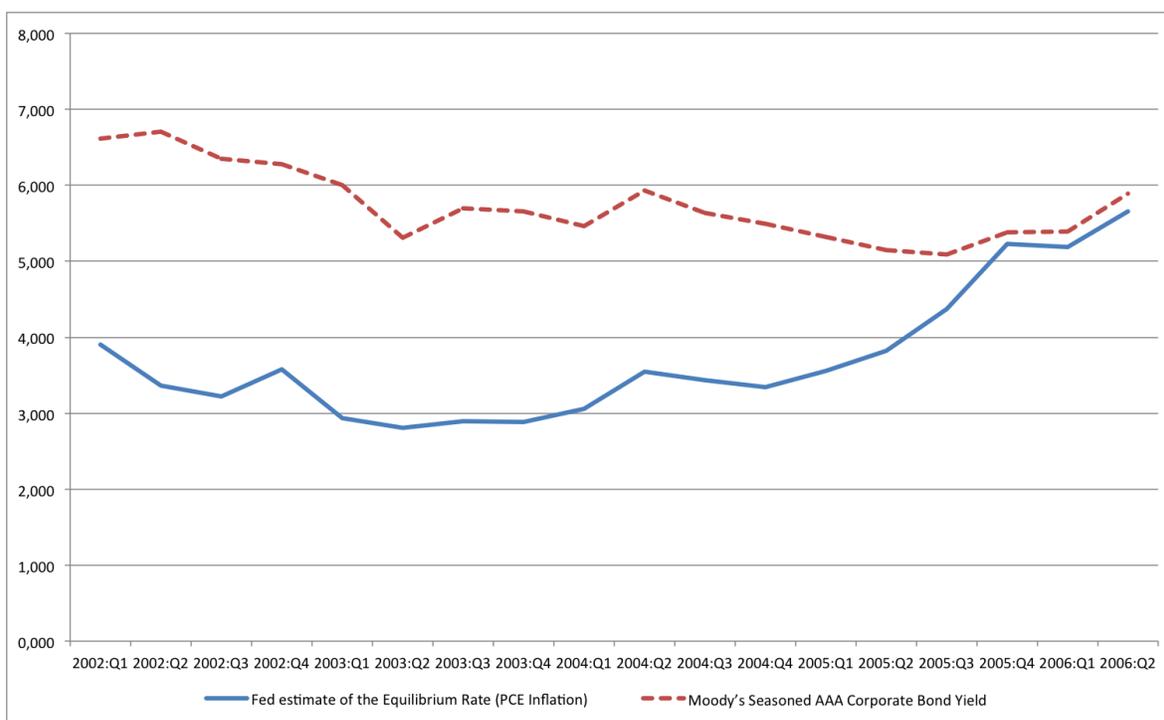


Figure 4.2 – Effective Funds Rate, Moody’s Seasoned AAA Corporate Bond Yield and Estimate Equilibrium Rate of Interest, 2002:Q1 - 2007Q4

glut” (Bernanke, 2005). A decisive contribution to this phenomenon was the tectonic shift in the early 1990s by much of the developing world from heavy emphasis on central planning to increasingly dynamic, export-led market competition. The result was a surge in growth in China and a large number of other emerging market economies that led to an excess of global intended savings relative to intended capital investment. According to the IMF, the marginal propensity to save in developing Asia has been above 40% for almost a decade and in the years before the sub-prime crisis of 2007, it rose to 55%. At the same time, investment ratios also rose, but by less. That ex-ante excess of savings propelled global long-term interest rates progressively lower between early 2000 and 2005. That decline in long-term interest rates across a wide spectrum of countries statistically explains - and is the most likely major cause of - real estate capitalization rates that declined and converged across the globe, resulting in the global housing price bubble.

Whatever is the explanation of the decreasing trend in the natural rate, it should be stressed that, since 2001, we observed a persistent wedge between a proxy of the natural interest rate \bar{i} and the Fed’s estimate of the equilibrium rate \hat{i}^* (Figure 4.2). The

	with constant	without constant
ϕ_1	1.030232*** (0.09208)	0.9480493** (0.037552)
ϕ_0	0.2107882 (0.21560)	
Observations	17	17
R-squared	0.8930	0.9755
<i>Standard errors in parentheses</i>		
* p<0.01 ** p<0.05 *** p<0.1		

Table 4.3 – Errors between Moody’s Seasoned AAA Corporate Bond Yield and Estimate Equilibrium Rate of Interest, Test of autocorrelation

gap appears to be systematic and persists until the end of 2005. Also in this case we check if the errors are really systematic or not. The results of the regression - similar to that we have seen with equation (4.7) - are presented in Table 4.3. The autocorrelation coefficient is positive and highly significant both if we consider the constant term ϕ_0 and if we omit it. Moreover, with a simple test, we can see that the null hypothesis $H_0 : \phi_1 = 1$ is not rejected. Therefore the gap between AAA Corporate Bond Yield and Fed’s estimate natural rate composes a difference-stationary stochastic process. It is a *random walk* without drift that can be represented as follows:

$$\varepsilon_t = \varepsilon_0 + \sum_{i=0}^{t-1} u_{t-i} \quad (4.8)$$

Far from being purely random, the error in the estimate of the natural rate is therefore the result of a *systematic* error of the central bank. The FRB/US econometric model used by the Fed underestimated from the beginning the value of the equilibrium rate. For this reason, since 2001, we observe a substantial gap between the two rates, and this initial error ε_0 - net of minor random deviations u_t - has remained basically unchanged until 2005.

4.5 Safer monetary policy: adaptive rule

To be honest, we can not say with certainty that the gap between the Moody’s Seasoned AAA Corporate Bond Yield and the forecast equilibrium rate by the Fed has been

caused by estimation errors. It may be that the Fed has estimated and published periodically in its Bluebook the equilibrium real rate, but then she have decided to use another set of indicators that have not been reported anywhere. For example, in a letter to Jim Saxton, the Chairman of the Fed warned that “*the reliance on a single summary measure such as a natural rate of interest would be unwise as a strategy for formulating monetary policy. Rather, a full consideration of current and prospective economic developments, and of the risks to the outlook, is essential for the conduct of monetary policy*” (Greenspan, 2005b).

However it is not clear what should be the reliable policy indicators for the former governor of the Fed. If the trend of the “safe” corporate bonds was a conundrum, same doubts were expressed by Greenspan on the use of the yield spread between the Fed funds rate and the 10-year bond yield. Despite the importance of a yield spread for monetary policy recognized by classical economists like Wicksell and Thornton and also by recent research of the Federal Reserve Bank of New York (Estrella, 2005), Greenspan does not seem to make much reference to this indicator in the choice of policies to be adopted¹⁵. In fact, he declared that the yield spread “[...] *is no longer useful as a leading indicator to the extent that it was*” (Greenspan, 2005a). To support his position Greenspan cited the case of the 1992-94 biennium in which the yield curve narrowed sharply even as the economy was entering the longest sustained expansion of the post-war period. With this he sought to demonstrate that a flattening of the yield curve is not a foolproof indicator of future economic weakness. In fact, many factors can affect the slope of the yield curve, and these factors do not all have the same implications for the future output growth. Economic theory identifies three basic factors that affect the slope of the yield curve: the current level of the real funds rate relative to the long run level, the level of near-term inflation expectations relative to expected inflation at longer horizons and the level of near-term risk premiums relative to risk premiums at longer horizons. Many statistical analysis indicates that the first factor is the key component from which the yield curve slope derives much of its predictive power for future GDP growth, while the connection with the two other factors is far less certain and likely to depend on economic circumstances. Greenspan was very clear on these points: “*A rise in near-term inflation expectations above long-term inflation expectations would tend to flatten the yield curve and might also signal a prospective weakening in aggregate demand. This configuration in inflation expectations might reflect adverse*

¹⁵Nevertheless the Conference Board conducts an ongoing evaluation of these indicators and especially thorough, major reevaluation of the composite was made in July 2005.

supply factors that have pushed up inflation expectations in the near term but that are expected to dissipate over time. In this case, the flattening of the yield curve might be a signal of an improving inflation picture that could also be accompanied by a favorable outlook for economic growth” (Greenspan, 2005b). Regarding the connection between output growth and risk premiums, Greenspan argued that “[...] a fall in distant horizon risk premiums would flatten the yield curve and might signal a weakening in economic activity. [...] But it is also possible that a decline in the risk premiums could be a sign that investors are generally more willing to bear risk. In this case, a flattening of the yield curve [...] could be an indicator of an easing in financial conditions that would stimulate future economic activity” (Greenspan, 2005b).

Therefore, according to the former governor of the Fed, the problem of lack of knowledge of the natural variables can not be solved with the use of proxies. These may have some descriptive value *ex-post*, but can not be used to determine the monetary policy decisions. Greenspan’s considerations are similar to what we have said in **Chapter 3**: the central bank, due to the presence of imperfect information, could set a wrong target on some variables. The idea that the central bank may sooner or later realize that the target set is wrong is not so obvious. Real and nominal variables are continuously hit by shocks and it may be not so easy to take a correction. As long as there is a gap between the short-term interest rate and the natural rate of interest, the economy is on an unsustainable and potentially explosive intertemporal path.

As Orphanides and Williams (2002b) show, a rule that does not make use of natural variables - or proxies of them - and conversely employs only observed macroeconomic variables may allow a reliable stabilization policy. To address this issue, we can simply assume the following feedback rule:

$$i_t = \lambda i_{t-1} + (1 - \lambda) [i_{t-1} + \gamma_\pi(\pi_t - \pi^*) + \gamma_y(y_t - y_{t-1})] \quad (4.9)$$

This rule introduces three important elements. First, it allows for inertial behavior in setting interest rates, $\lambda > 0$, which proves particularly important for policy analysis in models with strong expectational channels (Woodford, 2003). Second, it allows the policy response to the evolution of the *effective* output rather than the output-gap. Third, the natural rate of interest, instead of acting as an “anchor” of the system (as stated in the New Neoclassical Synthesis models), becomes a sort of “hidden attractor” and it does not appear explicitly in the rule.

It is interesting to note that the use of this type of rule between 2000 and 2007

would have guaranteed a trend of short-term interest rate very close to the long term rate. Following Kozicki (1999) and Rudebush (2002) we set the smoothing parameter $\lambda = 0.8$. If we use the policy coefficients suggested by Taylor - namely $\gamma_\pi = 1.5$ and $\gamma_y = 0.5$, the performance of the short-term nominal interest rate, while remaining consistently below the trend of the long-term rate, would have avoided the huge gap actually observed in that period (Figure 4.9). However, a better performance would have taken place with a lower inflation coefficient or considering only the dynamics of the output (Figure 4.10-4.11).

4.6 Conclusions

The Taylor rule has undoubtedly influenced the debate about monetary policy over the last 20 years. Economists everywhere recognize the Taylor rule's importance in monetary policymakers' decisions. The transcript from the FOMC meetings include several references to the rule (Kahn, 2012). However, the fact that Taylor rule has been referred to in the policy meetings does not necessarily imply that it has had a significant influence on the decisions.

The most common way to analyze the importance of the Taylor rule is simply to consider the correlation between the original Taylor rule and the actual federal funds rate. Based on this approach Taylor (2010) argues that the Fed followed the Taylor rule quite closely until around 2002. After that, he argues that the Fed abandoned the Taylor rule and moved to a more discretionary monetary policy. He sees the large deviation from the Taylor rule between 2002 and 2006 as a policy mistake that contributed to the build-up of financial imbalances and the subsequent crisis. Bernanke (2010) replied to Taylor by showing that a forward-looking Taylor rule would have implied an interest rate closer to the actual one. Nevertheless this explanation does not seem entirely satisfactory.

In this chapter we have seen that there are essentially two elements that can justify the Fed's monetary policy: the use of a different indicator of inflation - the PCE instead of the CPI - and the use of its own estimates of the natural rate of interest. Based on this empirical evidence it has been possible to identify the "true" Great Deviation, namely the one between the Fed's estimate of the natural rate of interest and the rate inferred from the performance of the long-term safe securities. This wedge was systematic and substantially constant throughout the period that we considered. This evidence seems to confirm all the doubts that the economic literature has placed on the reliability and

accuracy of the estimates of natural variables. Conversely, policy errors of the Fed, i.e. the gap between the effective federal funds rate and the rate implied by the Taylor rule, were marginal and completely random. The main message is thus that the error is not in the *application* of monetary policy rule, but *in* the rule.

On the basis of these results we find confirmation of two conclusions obtained in **Chapter 3**. The first is that the key element that eventually determines whether a rule is good or bad are not the parameters but the crucial piece of information about the natural rate of interest. A Taylor rule is not able to produce good results if the central bank is misinformed about this variable. On the contrary, monetary policy rules relying upon timely and precise knowledge of the natural rate of interest are destabilizing, allowing macroeconomic imbalances to grow. The second result is that, 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 are preferable.

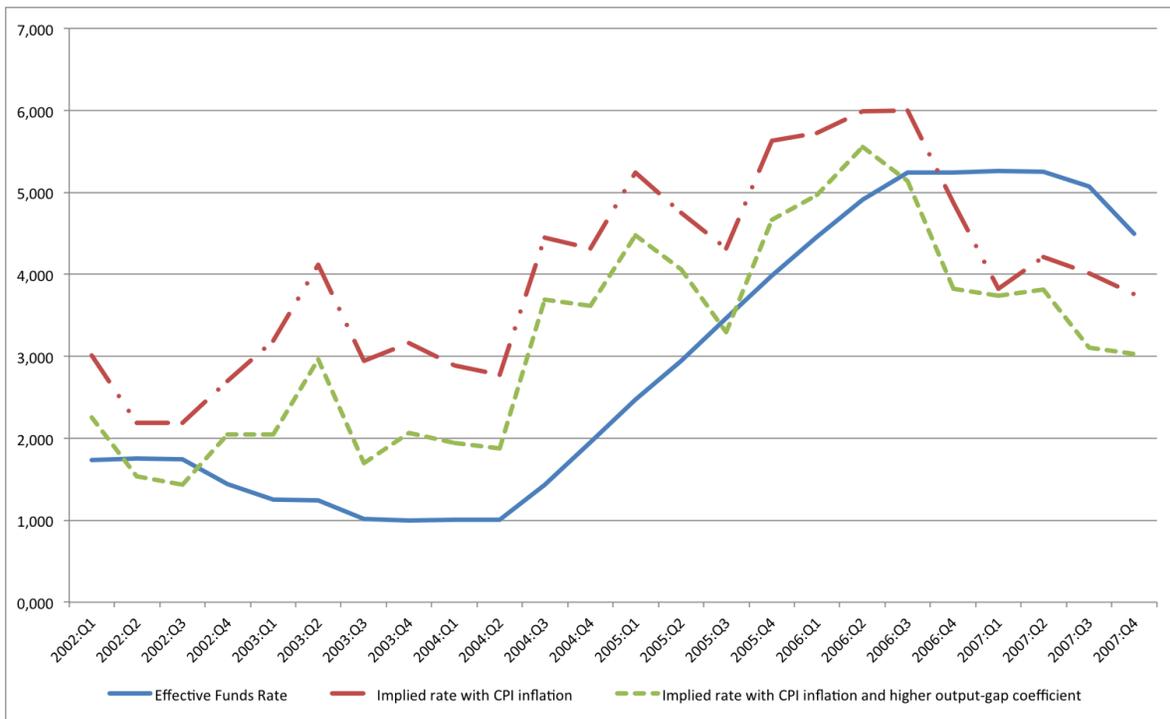


Figure 4.3 – Effective Funds Rate and Implied rate with CPI inflation, 2002:Q1 - 2007:Q4

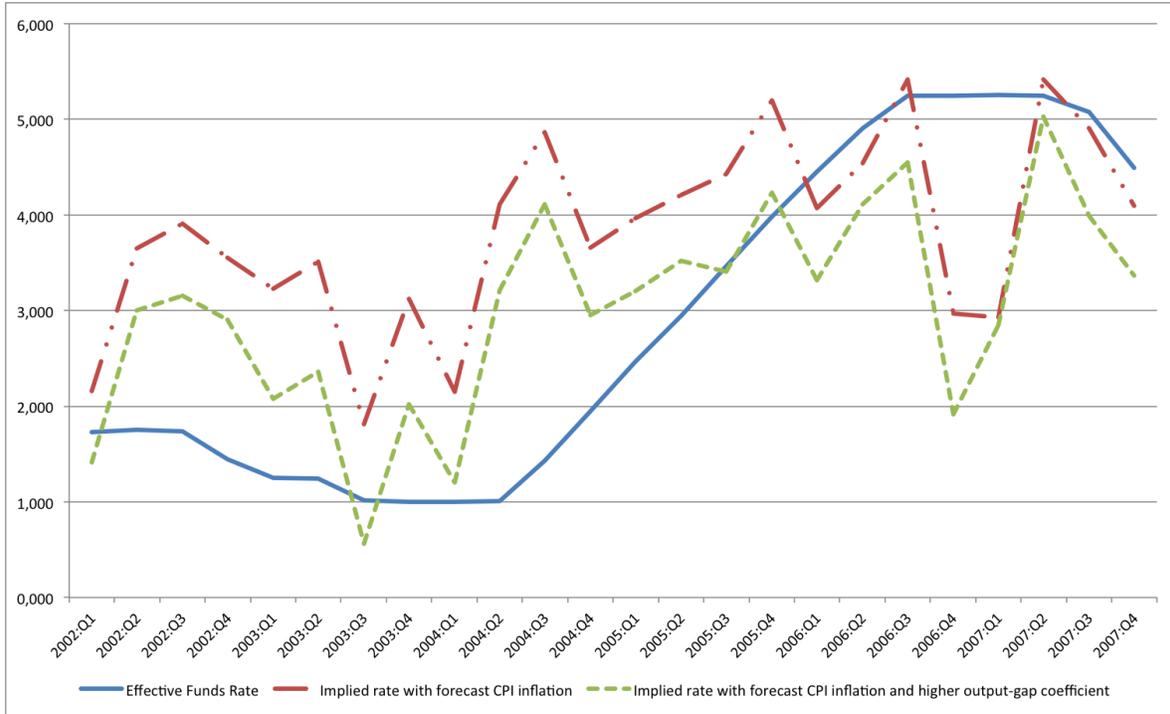


Figure 4.4 – Effective Funds Rate and Implied rate with forecast CPI inflation, 2002:Q1 - 2007:Q4

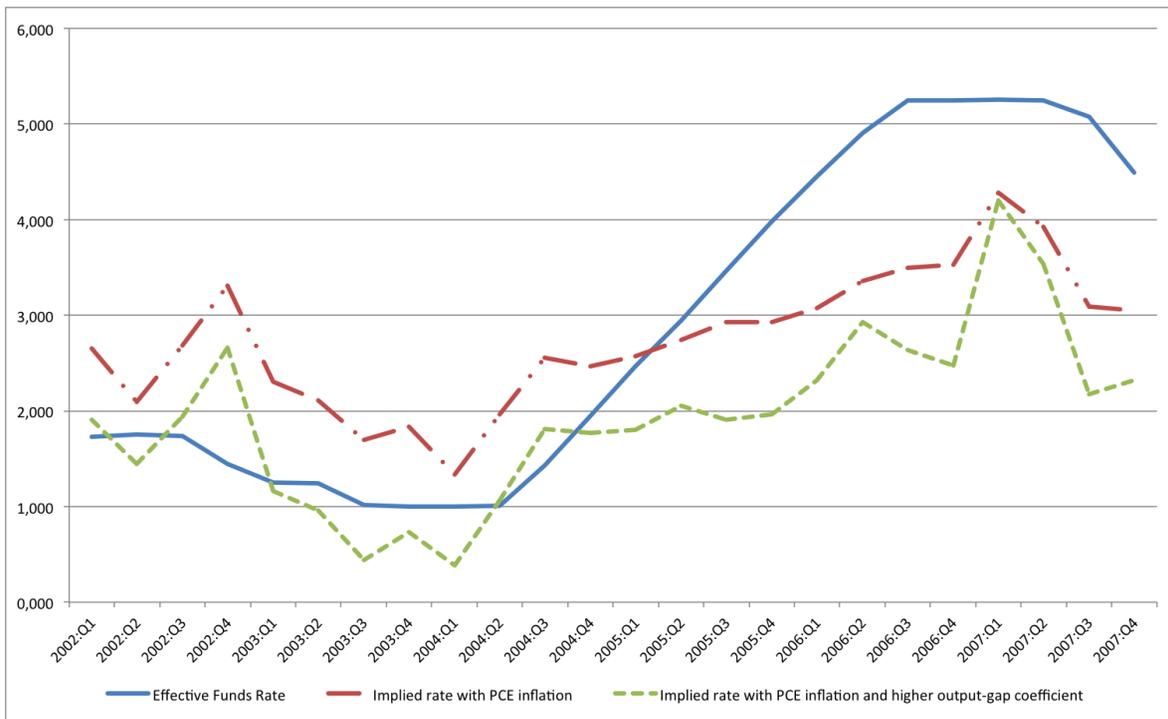


Figure 4.5 – Effective Funds Rate and Implied rate with PCE inflation, 2002:Q1 - 2007:Q4

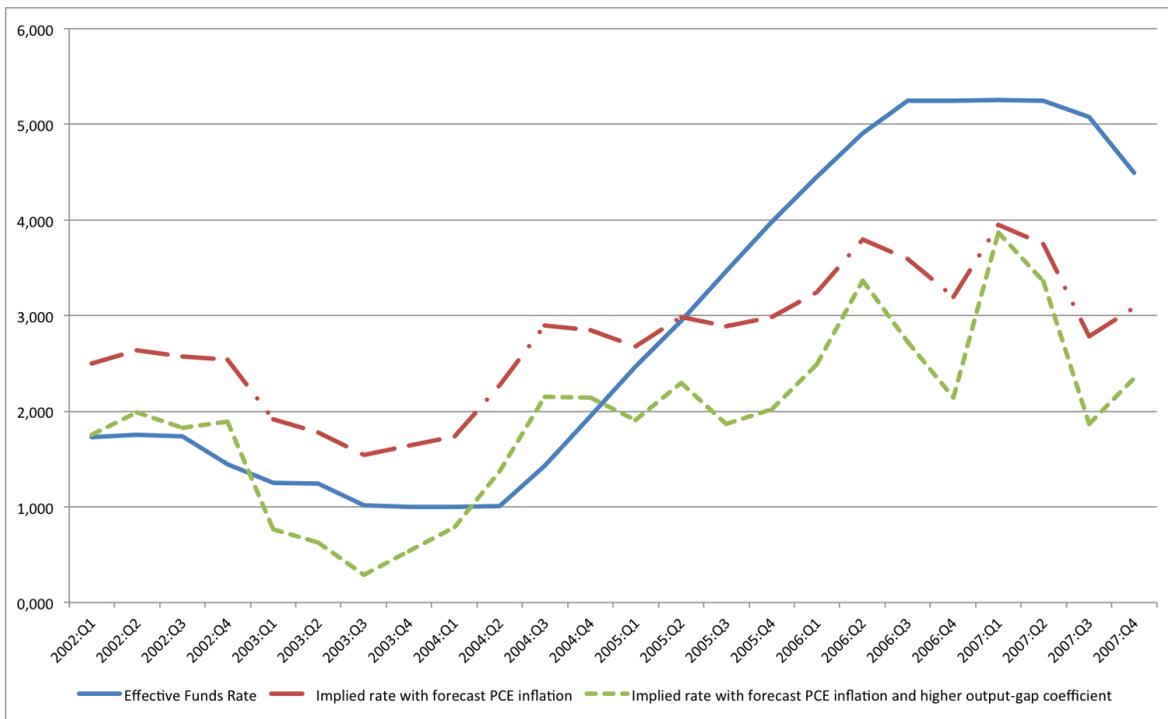


Figure 4.6 – Effective Funds Rate and Implied rate with forecast PCE inflation, 2002:Q1 - 2007:Q4

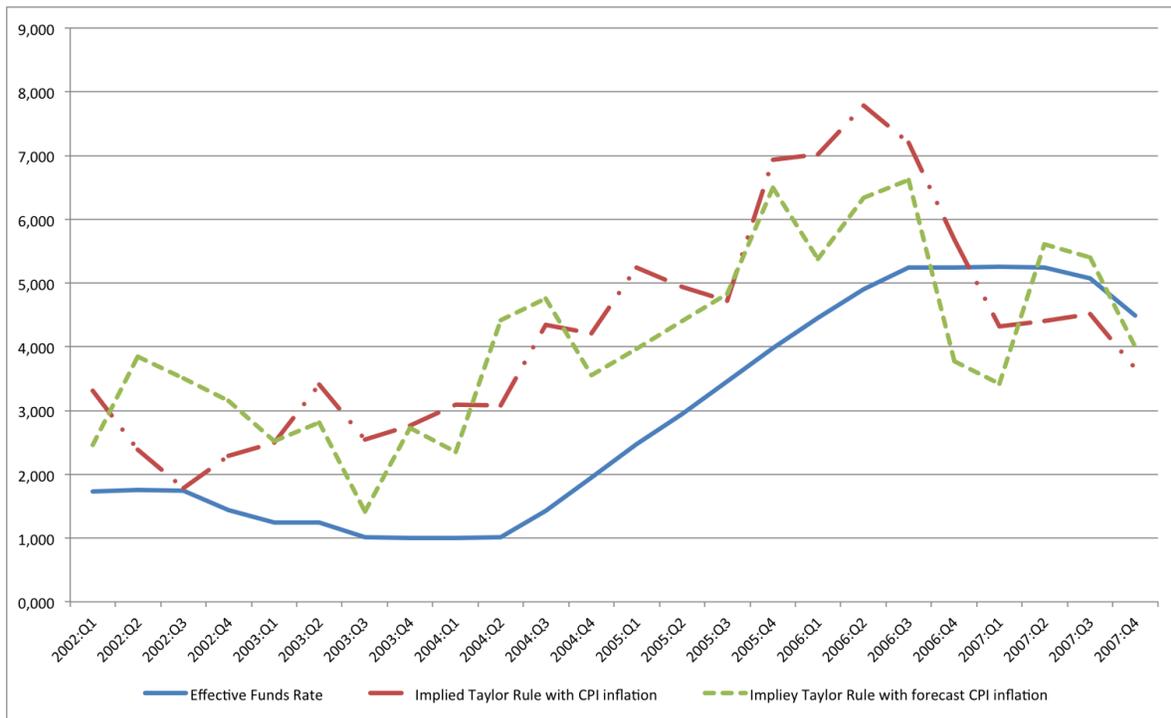


Figure 4.7 – Effective Funds Rate and Implied rate with estimate Equilibrium Real Rate and CPI inflation, 2002:Q1 - 2007:Q4

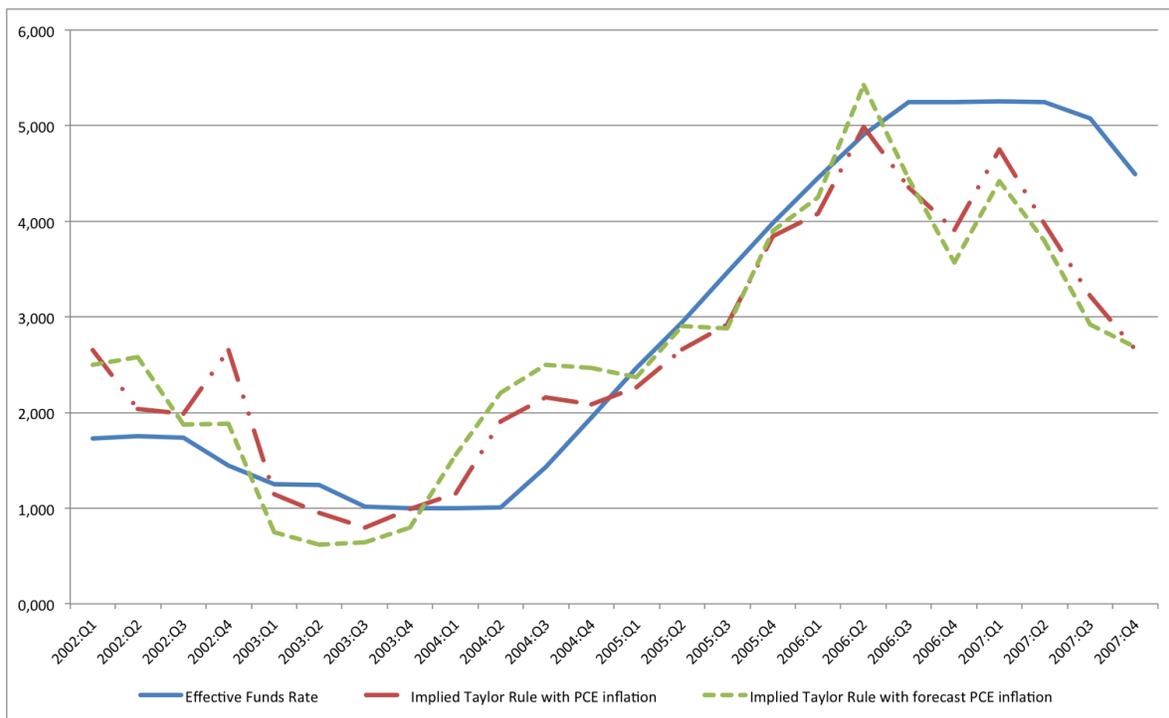


Figure 4.8 – Effective Funds Rate and Implied rate with estimate Equilibrium Real Rate and PCE inflation, 2002:Q1 - 2007:Q4

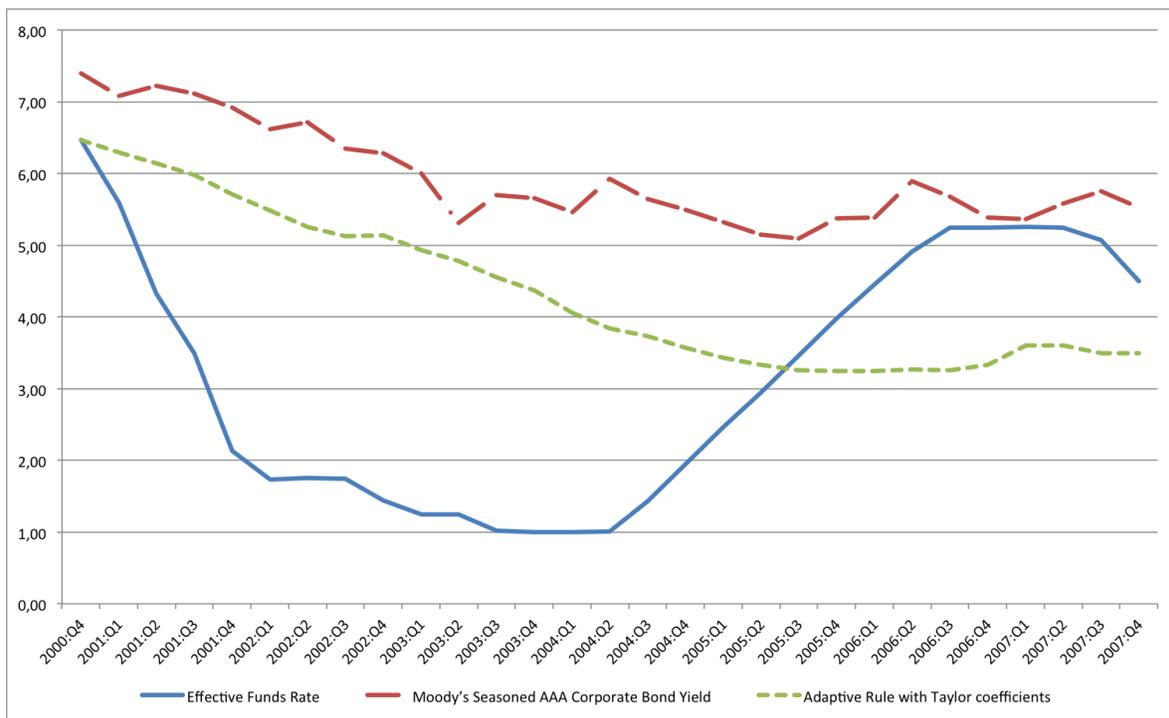


Figure 4.9 – Effective Funds Rate, Moodys Seasoned AAA Corporate Bond Yield and Implied rate with an adaptive rule with Taylor coefficients, 2000:Q4 - 2007:Q4

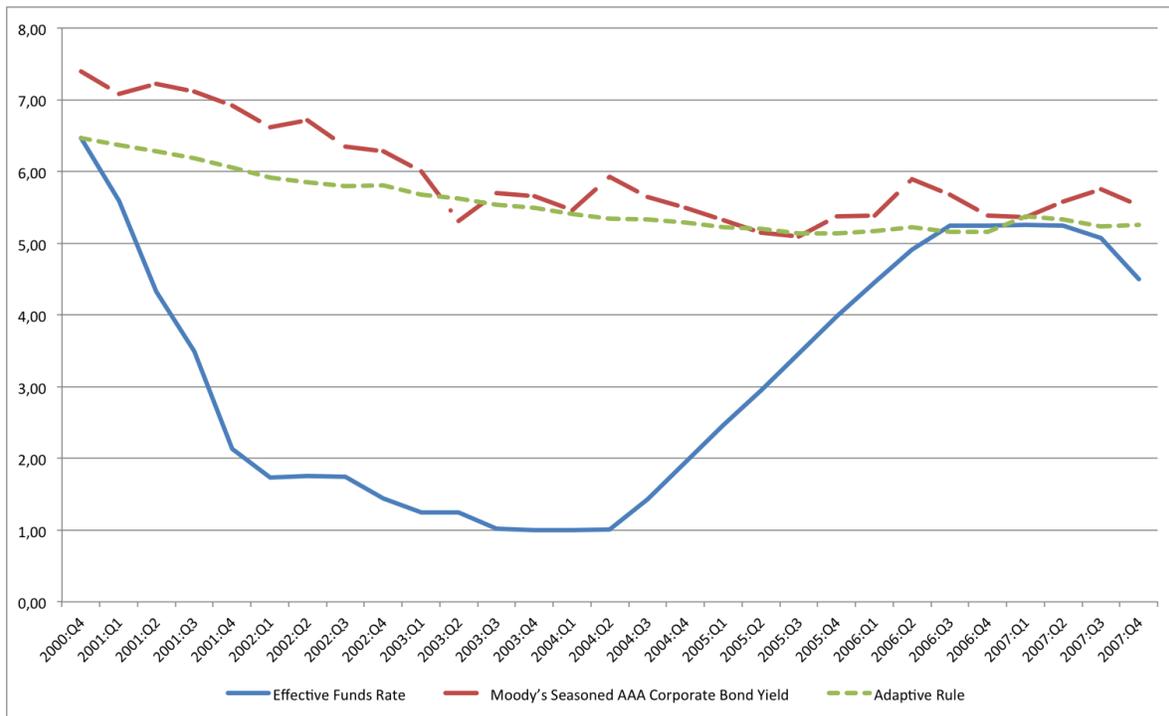


Figure 4.10 – Effective Funds Rate, Moodys Seasoned AAA Corporate Bond Yield and Implied rate with an adaptive rule with $\gamma_{\pi} = 0.5$ and $\gamma_y = 0.5$, 2000:Q4 - 2007:Q4

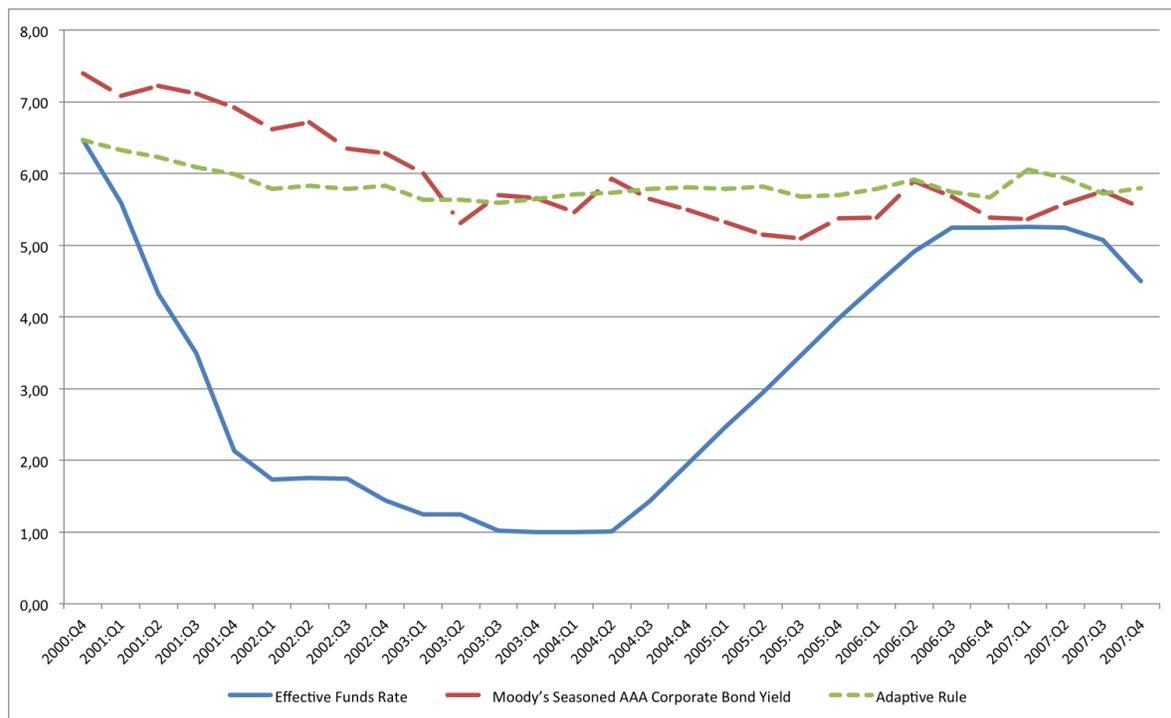


Figure 4.11 – Effective Funds Rate, Moodys Seasoned AAA Corporate Bond Yield and Implied rate with an adaptive rule with $\gamma_y = 1.0$, 2000:Q4 - 2007:Q4

Conclusions

Traditionally, monetary theory has had two main preoccupations: find a nominal anchor and obtain the stability of credit in order to avoid the formation of bubbles. The first problem was more or less neglected in the older central banking literature that took a metallic standard for granted. Monetary theory of the last forty years represents a break with the main tradition of central banking doctrine, which was concerned with controlling credit cycle to avoid financial crashes and bank panics. Today's theory may have rediscovered the importance of solvency of governments, but has rather lost the solvency of the private sector and more particularly of the banking system. In assuming that the economy is in intertemporal general equilibrium, it in effect assumes away the problems with which older central banking theories sought to cope. In particular, in the NNS models it is assumed that real interest rates coordinate consumption and production plans to maintain the economy always on the intertemporal efficiency frontier. Within such a conceptual framework, the only sensible function remaining for a central bank is to provide nominal stability by control of the short-term interest rate. Attempts to regulate real activity are as senseless as they are futile.

Recent episodes of financial crisis have seriously disputed this framework. The prevailing consensus is to view the crisis as the result of external shocks that could not have been anticipated. As Lucas (2009) argued “*one thing we are not going to have, now or ever, is a set of models that forecasts sudden falls in the value of financial assets, like the declines that followed the failure of Lehman Brothers in September 2008. This is nothing new. [...] If an economist had a formula that could reliably forecast crises a week in advance, say, then that formula would become part of generally available information and prices would fall a week earlier*”. In fact the world's problems did not come from an external shock. Since the mid-Nineties interest rates were too low, creating in several countries what Austrian economists called *intertemporal* problem. In essence what happens is that inappropriately low rates of interest bring forward investment spending

by households and business (adding to demand when it takes place) from “tomorrow” to “today” so that when “tomorrow” arrives, budget constraints reduce spending at precisely the time when “yesterday’s” investment comes on stream, adding to supply. Therefore, these imbalances result from failures of interest-rate mechanism to coordinate the plans of investors and savers. Empirically, these discrepancy among plans are hardly detectable directly from national accounts, since these are constructed in such a way that the investment-saving identity - augmented with the public and foreign sector - always holds. Nevertheless there are two main symptoms of investment-saving imbalances which indicate that the economy is moving *off* its intertemporal general equilibrium path. The first is a “cumulative process” of inflation, the second arises from the economy accommodating the opposite imbalance in a demultiplicative process of real economic activity and income. Both these symptoms arise from mechanisms in the economy that tend to restore investment-saving equality when this task is not performed by its due coordination device, namely the market real interest rate.

These out-of-equilibrium processes are nowadays a largely unexplored domain, abandoned by the DSGE macroeconomics for methodological inhibitions on the grounds that they cannot be dealt with rigorous criteria. But this is a controversial statement. In this thesis I proposed a modeling framework which is able to describe the effects of investment-saving imbalances by means of modern techniques, and by a specific model that is closely comparable to the standard NNS model. This approach has driven out the methodological inhibition from addressing processes that are out of (intertemporal) equilibrium.

Rejecting the hypothesis of perfect information, efficient financial markets and dynamic stability of the system, it was possible to obtain some important conclusions. First, investment-saving imbalances trigger *disequilibrium* business cycles with endogenous real as well as nominal effects, even with prices/wages flexibility. Second, these cycles display endogenously the autocorrelated dynamic structure that is typically observed in the data without any need to invoke further frictions and imperfections, as is done in the NNS approach. Third, these processes persist as long as the original misalignment of the market real interest rate with respect to the intertemporal general equilibrium rate persists.

The dynamic properties of the system with respect to the NNS standard model are thus considerably modified. This has important consequences in the implementation of monetary policy. The main conclusion to be drawn is that in this setup the real normative content of rule-based behaviour of the central bank is no longer clear. To

put it in a nutshell: the more detailed and information-laden is the rule, the larger is the scope of cases in which a change in the reaction function would be beneficial, and the greater is the damage that the rule can produce if the information requirements are not met. Thus central banks should take into account that the investment-saving imbalances deserve careful monitoring of symptoms, and that they require greater attention to the dynamic stability of choices of policy reaction functions. In this respect, we have seen that output fluctuations are more reliable signals for monetary policy than inflation and that adaptive rules are more robust than optimal rules based on direct information on natural rates.

Obviously this dissertation provides only a partial and incomplete analysis. The proposed model is able to explain some empirical evidence, but for the moment I can not go so far as to assert that the data confirm the validity of the model. Although it is clear that a boom (i.e. an excess demand and inflation today with too low market rate) may trigger its own bust (i.e. an excess supply and deflation tomorrow), the model is not able to explain the outbreak of a crisis. On the contrary, the system, instead of exploding, adjusts itself to *prevent* the crisis. Therefore, further research should involve a more explicit treatment of financial structures, asset prices and their relations to the evolution of the capital stock and hence to the concept of the natural rate of interest itself.

Another element to be explored concerns the formation of expectations. The problem is that, in the event of a (persistent) interest-rate gap, the future path of the price level will no longer be the same as the past. In other words, in the course of the cumulative process, expectations of return to normality are systematically falsified. Whereas the NNS tends to rule this problem out of analysis by focusing exclusively on states of the economy where expectations are statistically correct, in the model I presented I tried to describe a wider range of possibilities. However expectations remained “static”, in the sense that there were not changes in the presence of particular events. It is a very strong limitation. A better explanation may be to assume that agents learn during the cumulative process. A learning mechanism could thus shift expectations from static to adaptive to forward-looking and eventually rational in the sense of self-fulfilling. This fact may further modify the dynamic properties of the system.

References

- Aghion, P., Frydman, R., Stiglitz, J. E., Woodford, M., 2004. Information and Expectations in Modern Macroeconomics: in Honor of Edmund S. Phelps. Princeton, NJ: Princeton University Press.
- Ahearne, A., Gagnon, J., Haltmaier, J., Kamin, S., 2002. Preventing deflation: Lessons from japan's experience in the 1990s. International Finance Discussion Papers. Board of Governors of FED System 72.
- Akerlof, G. A., Yellen, J. L., 1985a. Can small deviations from rationality make significant differences to economic equilibria? *American Economic Review* 75, no. 4, 708–720.
- Akerlof, G. A., Yellen, J. L., 1985b. A near-rational model of the business cycle, with wage and price inertia. *Quarterly Journal of Economics* 100, no. 5, 823–838.
- Alesina, A., Summers, L. H., 1993. Central bank independence and macroeconomic performance: Some comparative evidence. *Journal of Money, Credit and Banking* 25, no. 2, 151–162.
- Amato, J. D., 2005. The role of the natural rate of interest in monetary policy. BIS Working Paper 171.
- Andres, J., Lopez-Salido, J., Nelson, E., 2009. Money and the natural rate of interest: Structural estimates for the united states and the euro area. *Journal of Economic Dynamic and Control* 33, no. 3, 758–776.
- Andrews, D., 1993. Testing for parameter instability and structural change with unknown change points. *Econometrica* 61, 821–856.
- Asso, P. F., Kahn, G. A., Leeson, R., 2007. The taylor rule and the transformation of monetary policy. Federal Reserve Bank of Kansas City Research Working Paper RWP 07-11.

- Balfoussia, H., Brissimis, S. N., Delis, M. D., 2011. The theoretical framework of monetary policy revisited. Bank of Greece working papers 138.
- Ball, L., Mankiw, G. N., Romer, D., 1988. The new keynesian economics and the output-inflation trade-off. *Brookings Papers on Economic Activity* 1, 1–65.
- Ball, L., Romer, D., 1990. Real rigidities and the non-neutrality of money. *Review of Economic Studies* 57, no. 2, 183–203.
- Barro, R. J., Gordon, R., 1983. Rules, discretion and reputation in a model of monetary policy. *Journal of Monetary Economics* 12, 101–121.
- Basdevant, O., Björkstén, N., Karagedikli, Ö., 2004. Estimating a time varying neutral real interest rate for new zealand. Reserve Bank of New Zealand Discussion Paper Series 1.
- Bean, C., 2003. Asset prices, financial imbalances and monetary policy: Are inflation targets enough. BIS Working Paper 140.
- Beenstock, M., Ilek, A., 2010. Wicksell's classical dichotomy: Is the natural rate of interest independent of the money rate of interest? *Journal of Macroeconomics* 32, no. 1, 366–377.
- Benigno, P., 2002. A simple approach to international monetary policy coordination. *Journal of International Economics* 57, no. 1, 177–196.
- Bernanke, B. S., 2004. The great moderation. Eastern Economic Association, Washington, DC.
- Bernanke, B. S., 2005. The global saving glut and the us current account deficit. In: F. R. B. of St. Louis (ed.). Homer Jones Lecture. St. Louis, Missouri.
- Bernanke, B. S., 2010. Monetary policy and the housing bubble. Speech at the Annual Meeting of the American Economic Association Atlanta, Georgia.
- Bernanke, B. S., Gertler, M., 1999. Monetary policy and asset price volatility. Federal Reserve Bank of Kansas City Proceedings 77–128.
- Bernanke, B. S., Gertler, M., 2001. Should central banks respond to movements in asset prices? *American Economic Review* 91, no. 2, 253–257.
- Blanchard, O., 1997. Comment (on goodfriend and king). *NBER Macroeconomics Annual* 12, 289–293.

- Blanchard, O., 2000. What do we know about Macroeconomics that Fisher and Wicksell did not? *Quarterly Journal of Economics* 115, 1375–1409.
- Blanchard, O., 2008. The state of macro. NBER Working Paper 14259.
- Blanchard, O., Fischer, S., 1989. *Lectures in Macroeconomics*. Massachusetts: MIT Press.
- Blanchard, O., Galí, J., 2005. Real wage rigidities and the new keynesian model. NBER Working Paper 11806.
- Blanchard, O., Kahn, C. M., 1980. The solution of linear difference models under rational expectations. *Econometrica* 48, no. 5, 1305–1311.
- Blanchard, O., Kiyotaki, N., 1987. Monopolistic competition and the effects of aggregate demand. *American Economic Review* 77, 647–666.
- Blinder, A. S., 1994. On sticky prices: Academic theories meet the real world. In: G. N. Mankiw (ed.). *Monetary Policy*. Chicago: The University of Chicago Press.
- Blinder, A. S., 1998. *Central banking in theory and practice*. MIT Press.
- Boianovsky, M., Trautwein, H. M., 2006a. Price expectations, capital accumulation and employment: Lindahl's macroeconomics from the 1920s to the 1950s. *Cambridge Journal of Economics* 30, 881–900.
- Boianovsky, M., Trautwein, H. M., 2006b. Wicksell after Woodford. *Journal of History of Economic Thought* 28, no. 2, 171–186.
- Bordo, M. D., Dueker, M. J., Wheelock, D. C., 2000. Aggregate price shocks and financial instability: A historical analysis. NBER Working Paper 7652.
- Borio, C., 2008. The financial turmoil of 2007-? a preliminary assessment and some policy considerations. BIS Working Paper 251.
- Borio, C., Disyatat, P., 2011. Global imbalances and the financial crisis: Link or no link? BIS Working Paper 346.
- Borio, C., Lowe, P., 2002. Asset prices, financial and monetary stability: Exploring the nexus. BIS Working Paper 114.
- Bratsiotis, G. J., Martin, C., 2003. Monetary Policy Rules, Real Rigidity and Endogenous Persistence. Public Policy Discussion Papers 02-31, Economics and Finance Section, School of Social Sciences, Brunel University.

- Brock, W. A., Hommes, C. H., 1997. A rational route to randomness. *Econometrica* 65, no. 5, 1059–1096.
- Brock, W. A., Hommes, C. H., 1998. Heterogeneous beliefs and routes to chaos in a simple asset pricing model. *Journal of Economic Dynamic and Control* 22, no. 8-9, 1235–1274.
- Caballero, R., Farhi, E., Gourinchas, P., 2008. An equilibrium model of global imbalances and low interest rates. *American Economic Review* 58, 358–393.
- Caballero, R. J., 2010. Macroeconomics after the crisis: Time to deal with the pretense-of-knowledge syndrome. *Journal of Economic Perspectives* 24, no. 4, 85–102.
- Calomiris, C., Hanes, C., 1995. Historical macroeconomics and macroeconomic history. In: K. Hoover (ed.). *Macroeconometrics: Developments, Tensions and Prospects*. Kluwer: Dordrecht. 351–416.
- Calvo, G. A., 1983. Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics* 12, no. 3, 383–398.
- Canzoneri, M., Cumby, R., Diba, B., 2004. The cost of nominal inertia in nns model. NBER Working Paper 10889.
- Canzoneri, M., Cumby, R., Diba, B., Lopez-Salido, D., 2008. Monetary aggregates and liquidity in a neo-wicksellian framework. NBER Working Paper 14244.
- Carare, A., Tchaidze, R., 2004. The use and abuse of taylor rules. how precisely can we estimate them? IMF Working Paper WP/05/148.
- Caresma, J. C., Gnan, E., Ritzberger-Grünwald, D., 2005. The natural rate of interest. concepts and appraisal for the euro area. *Monetary Policy and the Economy* Australian National Bank, no. Q4.
- Carlton, D. W., 1986. The rigidity of prices. *American Economic Review* 76, no. 4, 637–658.
- Casares, M., 2002. Time to build approach in a sticky price, sticky wage optimizing model. European Central Bank Working Paper Series 147.
- Casares, M., McCallum, B. T., 2000. An optimizing is-lm framework with endogenous investment. NBER Working Paper 7908.
- Cassel, G., 1918. *Theoretische Sozialökonomie*. Leipzig: C.F. Winter.
- Chick, V., 1983. *Macroeconomics After Keynes*. Oxford: Oxford University Press.

- Christiano, L. J., Eichenbaum, M., Evans, C., 2001. Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy* 113, 1–45.
- Christiano, L. J., Ilut, C. L., Motto, R., Rostagno, M., 2010a. Monetary policy and stock market booms. NBER Working Paper 16402.
- Christiano, L. J., Motto, R., Rostagno, M., 2010b. Financial factors in economic fluctuations. ECB Working Paper 1192.
- Christiano, L. J., Todd, R. M., 1996. Time to plan and aggregate fluctuations. *Federal Reserve Bank of Minneapolis Quarterly* 20, no. 1, 14–27.
- Clarida, R., 2010. The mean of the new normal is an observation rarely realised: Focus also on the tails. *Pimco Global Perspectives* July.
- Clarida, R., Galí, J., Gertler, M., 1999. The science of monetary policy: A new keynesian perspective. *Journal of Economic Literature* 37, no. 4, 1661–1707.
- Clarida, R., Galí, J., Gertler, M., 2000. Monetary policy and macroeconomic stability: Evidence and some theory. *Quarterly Journal of Economics* 115, no. 1, 147–180.
- Clark, T., Kozicki, S., 2005. Estimating equilibrium real interest rates in real time. *The North American Journal of Economics and Finance* 16, no. 3, 395–413.
- Cooper, R., 2004. Monopolistic competition and macroeconomics: Theory and quantitative implications. In: S. Brakman, B. J. Heijdra (eds.). *The Monopolistic Competition Revolution in Retrospect*. Cambridge: Cambridge University Press. 375–398.
- Cuaresma, J., Gnan, E., Ritzberger-Gruenwald, D., 2004. Searching for the natural rate of interest: a euro area perspective. *Empirica* 31, no. 2, 185–204.
- Curda, V., Woodford, M., 2009. Credit frictions and optimal monetary policy. BIS Working Paper 278.
- De Antoni, E., 2009. Money and Finance: the Heterodox view of Robert Clower, Axel Leijonhufvud and Hyman Minsky. Discussion Paper 08/2009, Department of Economics, University of Trento.
- De Grauwe, P., 2010. The scientific foundation of dynamic stochastic general equilibrium models. *Public Choice* 144, 413–443.
- De Vroey, M. R., Malgrange, P., 2011. The History of Macroeconomics from Keynes's General Theory to the Present. Discussion Paper 2011028, Institut de Recherches Economiques et Sociales, Université catholique de Louvain.

- Debreu, G., 1974. Excess demand functions. *Journal of Mathematical Economics* 1, no. 1, 15–21.
- Dixit, A., Stiglitz, J. E., 1977. Monopolistic competition and optimum product diversity. *American Economic Review* 67, 297–308.
- Dueker, M. J., Rasche, R. H., 2004. Discrete policy changes and empirical models of the federal funds rate. *Federal Reserve Bank of St. Louis Review* 86, no. 6, 61–72.
- ECB, 2004. The natural real interest rate in the euro area. *ECB Monthly Bulletin* May.
- Eichenbaum, M., Fisher, J. D., 2004. Evaluating the calvo model of sticky prices. NBER Working Paper 10617.
- Eisner, R., Strotz, R. H., 1963. *Determinants of Business Investment*. New Jersey: Englewood Cliffs.
- Ellison, M., Scott, A., 2000. Sticky prices and volatile output. *Journal of Monetary Economics* 46, no. 3, 621–632.
- Estrella, A., 2005. Connected to the problems of identifying the natural rate of interest is that involving the spreading. *The Economic Journal* 115, 722–744.
- Evans, G. W., Honkapohja, S., 2001. *Learning and Expectations in Macroeconomics*. Princeton: Princeton University Press.
- Felipe, J., Adams, G. F., 2005. The estimation of the cobb-douglas function: a retrospective view. *Eastern Economic Journal* 31, no. 3, 427–445.
- Felipe, J., Fisher, F. M., 2003. Aggregation in production functions: What applied economists should know. *Metroeconomica* 54, no. 2-3, 208–62.
- Ferguson, R. W., 2004. *The Equilibrium Real Rate of Interest*. Remarks by Vice Chairman Roger W. Ferguson Jr. October 29th, University of Connecticut School of Business Graduate Learning Center, Hartford, Connecticut.
- Fernandez-Villaverde, J., Rubio-Ramirez, J. F., 2007. How structural are structural parameters? NBER Working Paper 13166.
- Fischer, S., 1977. Long term contracts, rational expectations, and the optimal money supply rule. *Journal of Political Economy* 85, no. 191-205.
- Fodor, G. G., 1994. Sull'autonomia delle banche centrali. In: L. Bosco, F. Targetti, R. Tamborini (eds.). *L'Italia e l'Europa oltre Maastricht*. Trento: Banca di Trento e Bolzano. 207–215.

- FOMC, August 2003. Transcript of fomc meetings. Federal Reserve Bank
<http://www.federalreserve.gov/fomc/transcripts>.
- FOMC, January 2004. Transcript of fomc meetings. Federal Reserve Bank
<http://www.federalreserve.gov/fomc/transcripts>.
- FOMC, June 1999. Transcript of fomc meetings. Federal Reserve Bank
<http://www.federalreserve.gov/fomc/transcripts>.
- Francis, N., Ramey, V., 2003. The source of historical economic fluctuations: an analysis using long-run restrictions. Department of Economics, University of California in San Diego .
- Francis, N., Ramey, V., 2005. Is the technology driven real business cycle hypothesis dead? shocks and aggregate fluctuations revisited. *Journal of Monetary Economics* 52, no. 8, 1379–1399.
- Friedman, M., 1959. *A Program for Monetary Stability*. New York: Fordham University Press.
- Friedman, M., 1963. Inflation: Causes and consequences. In: *Dollars and Deficits: Living with America's Economic Problems*. Prentice Hall: Eaglewood Cliffs, NJ. 21–71.
- Friedman, M., 1968. The role of monetary policy. *American Economic Review* 58, 1–17.
- Friedman, M., Friedman, R. D., 1980. *Free to Choose*. New York: Harcourt Brace Jovanovich.
- Fuster, A., Laibson, D., Mendel, B., 2010. Natural expectations and macroeconomic fluctuations. *Journal of Economic Perspectives* 24, no. 4, 67–84.
- Galí, J., 1999. Technology, employment and the business cycle: do technology shocks explain aggregate fluctuation? *American Economic Review* 89, 249–271.
- Galí, J., Gertler, M., Lopez-Salido, D., 2001. European inflation dynamics. *European Economic Review* 45, no. 7, 1237–1270.
- Galí, J., Monacelli, T., 2002. Monetary Policy and Exchange Rate Volatility in a Small Open Economy. CEPR Discussion Paper 3346.
- Garnier, J., Wilhelmsen, B. R., 2005. The natural rate of interest and the output gap in the euro area. a joint estimation. *European Central Bank Working Paper Series* 546.

- Gerdesmeier, D., Reimers, H. E., Roffia, B., 2009. Asset price misalignments and the role of money and credit. European Central Bank Working Paper Series 1068.
- Gerlach, S., Moretti, L., 2011. Monetary policy and tips yields before the crisis. CEPR Discussion Paper 8560.
- Giammarioli, N., Valla, N., 2003. The natural rate of interest in the euro area. European Central Bank Working Paper Series 233.
- Gnan, E., Ritzberger-Gruenwald, D., 2005. The natural rate of interest. concept and appraisal for the euro area. Monetary Policy and the Economy Q4.
- Goodfriend, M., King, R. G., 1998. The New Neoclassical Synthesis and the Role of Monetary Policy. Working Paper 98-05, Federal Reserve Bank of Richmond.
- Goodfriend, M., McCallum, B. T., 2007. Banking and interest rates in monetary policy analysis: a quantitative exploration. *Journal of Monetary Economics* 54, 1480–1507.
- Goodhart, C. A., 1999. Central bankers and uncertainty. *Bank of England Quarterly Bulletin* 39, 102–114.
- Greenspan, A., 1993. Testimony of Alan Greenspan before the Committee on Banking, Finance, and Urban Affairs, U.S. House of Representatives. Government Printing Office, Washington: U.S. House of Representatives, July 20, Washington.
- Greenspan, A., 1997. Rule vs. discretionary monetary policy. Remarks at the 15th Anniversary Conference of the Center for Economic Policy Research at Stanford University Stanford, California.
- Greenspan, A., 2004. Risk and uncertainty in monetary policy. *American Economic Review: Papers and Proceedings* 94, no. 2.
- Greenspan, A., 2005a. Hearing of the Federal Reserve Governor, Washington DC - November, 3rd. Joint Economic Committee.
- Greenspan, A., 2005b. Letter to Jim Saxton, Chairman of the Joint Economic Committee, Washington. Board of Governors of the Federal Reserve System.
- Greenspan, A., 2009. The fed didn't cause the housing bubble. *The Wall Street Journal* 11th March.
- Greenwald, B. C., Stiglitz, J. E., 1987. Keynesian, new keynesian and new classical economics. *Oxford Economic Papers* 39, 119–133.
- Greenwald, B. C., Stiglitz, J. E., 1993. New and old keynesians. *Journal of Economic*

- Perspectives 7, 23–44.
- Greenwald, B. C., Stiglitz, J. E., 2003. *Towards a New Paradigm in Monetary Economics*. Cambridge: Cambridge University Press.
- Grossi, M., Tamborini, R., 2011. Stock prices and monetary policy. re-examining the issue in a new keynesian model with endogenous investment. *Economic E-Journal*, Discussion Paper 54.
- Hahn, F. H., Solow, R., 1995. *A Critical Essay on Modern Macroeconomic Theory*. Cambridge, Massachussets: MIT Press.
- Hall, R., 1986. Market structure and macroeconomic fluctuations. *Brookings Papers on Economic Activity* 2, 265–338.
- Hall, R., 1990. Invariance properties of solow’s productivity residual. In: P. Diamond (ed.). *Growth, Productivity, Unemployment: Essays to Celebrate Bob Solow’s Birthday*. Cambridge, Massachussets: MIT Press. 71–112.
- Hall, S., Walsh, M., Yates, A., 1997. How do uk companies set prices? *Bank of England working papers* 67.
- Hansen, L. P., Sargent, T., 2008. *Robustness*. Princeton, NJ: Princeton University Press.
- Hansen, L. P., Sargent, T. J., 2001. Robust control and model uncertainty. *American Economic Review: Papesr and Proceedings* 91, 60–66.
- Hargreaves-Heap, S. P., 1992. *The New Keynesian Macroeconomics. Time, Belief and Social Interdependence*. London: Elgar.
- Hartley, J., 1994. *Tehnology in Macroeconomic Models*. Phd dissertation, University of California, Davis.
- Hauptmeier, S., Heinemann, F., Kappler, M., Kraus, M., Schrimpf, A., Trautwein, H. M., Wang, Q., 2009. *Methodische Fragen mittelfristiger gesamtwirtschaftlicher Projektionen am Beispiel des Produktionspotenzials*. Mannheim: ZEW Economic Studies.
- Hicks, J. R., 1937. Mr. keynes and the classics. *Econometrica* 5, 147–159.
- Howitt, P., 2012. What have central bankers learned from modern macroeconomic theory? *Journal of Macroeconomics* 34, no. 1, 11–22.
- Iacoviello, M., 2005. House prices, borrowing constraints and monetary policy in the

- business cycle. *American Economic Review* 95, 739–764.
- Jeanne, O., 1998. Generating real persistent effects of monetary shocks: How much nominal rigidity do we really need? *European Economic Review* 42, no. 6, 1009–1032.
- Jorgenson, D., Griliches, Z., 1967. The explanation of productivity change. *Review of Economic Studies* 34, no. 3, 249–83.
- Justiniano, A., Primiceri, G., 2010. Measuring the equilibrium real interest rate. *Federal Reserve Bank of Chicago Economic Perspectives* 34, no. 1, 14–27.
- Kahn, G. A., 2012. The taylor rule and the practice of central banking. In: E. Koenig, R. Leeson, G. Kahn (eds.). *The Taylor Rule and the Transformation of Monetary Policy*. Hoover Institution Press, Stanford University.
- Keynes, J. M., 1930. *A Treatise on Money*, vol. 1: *The Pure Theory of Money*. Vol 2: *The Applied Theory of Money*. London: Macmillan.
- Keynes, J. M., 1936. *The General Theory of Employment, Interest and Money*. London: Macmillan.
- Keynes, J. M., 1937a. Alternative theories of the rate of interest. *Economic Journal* 47, 210–215.
- Keynes, J. M., 1937b. The ex-ante theory of the rate of interest. *Economic Journal* 47, 215–222.
- Keynes, J. M., 1937c. The general theory of employment. *Quarterly Journal of Economics* 14, 109–123.
- Kiley, M. T., 1997. Efficiency wages, nominal rigidities and the cyclical behavior of real wages and marginal cost. *Economics Letters* 56, no. 2, 215–221.
- King, R. G., Rebelo, S. T., 2000. Resuscitating real business cycles. NBER Working Paper 7534.
- Kohn, D. L., 2007. John taylor rules. In: *Speech given at the Conference on John Taylor's Contributions to Monetary Theory and Policy*. Texas: Federal Reserve Bank of Dallas.
- Kozicki, S., 1999. How useful are taylor rules for monetary policy. *Economic Review* 84, no. 2.
- Kreps, D., 1990. *A Course in Microeconomic Theory*. Princeton: Princeton University

- Press.
- Kydland, F. E., Prescott, E. C., 1977. Rules rather than discretion: The inconsistency of optimal plans. *Journal of Political Economy* 85, no. 3, 473–491.
- Kydland, F. E., Prescott, E. C., 1982. Time to build and aggregate fluctuations. *Econometrica* 50, no. 6, 1345–1370.
- Laidler, D. W., 1991. *The Golden Age of the Quantity Theory*. London: Harvester Wheatsheaf.
- Laidler, D. W., 2006. Woodford and wicksell on “interest and prices”. the place of the pure credit economy in the theory of monetary policy. *Journal of History of Economic Thought* 28, 151–160.
- Laidler, D. W., 2009. Financial stability, monetarism and the wicksell connection. *Review of Economic Analysis* 1, no. 1, 60–79.
- Laidler, D. W., 2011. Natural hazards: Some pitfalls on the path to a neutral interest rate. C.D. Howe Institute Backgrounder 140.
- Larsen, J., McKeown, J., 2004. The informational content of empirical measures of real interest rate and output gaps for the united kingdom. Bank of England working papers 224.
- Laubach, T., Williams, J. C., 2003. Measuring the natural rate of interest. *The Review of Economics and Statistics* 85, 1063–1070.
- Leijonhufvud, A., 1981. The wicksell connection: Variations on a theme. In: *Information and Coordination. Essays in Macroeconomic Theory*. New York: Oxford University Press. 131–202.
- Leijonhufvud, A., 1992. Keynesian economics: Past confusions, future prospects. In: A. Vercelli, N. Dimitri (eds.). *Macroeconomics: A Survey of Research Strategies*. Oxford University Press.
- Leijonhufvud, A., 2007. Monetary and financial stability. CEPR Policy Insight 14.
- Leijonhufvud, A., 2009. Macroeconomics and the crisis: A personal appraisal. CEPR Discussion Paper 41.
- Lindahl, E. R., 1930. *Penningpolitikens medel*. (tr. 1939: Part II, “The Interest Rate and the Price Level” in *Studies in the Theory of Money and Capital*, Allen and Unwin, London). Malmö: Förlagsaktiebolaget.

- Lindahl, E. R., 1939. *Studies in the Theory of Money and Capital*. New York: Farrar and Rinehart.
- Lombardi, M. J., Sgherri, S., 2007. (un)naturally low? sequential monte carlo tracking of the us natural interest rate. ECB Working Paper 794.
- Long, J. B., Plosser, C. I., 1983. Real business cycle. *Journal of Political Economy* 91, no. 1, 39–69.
- Lucas, R. E., 1967. Adjustment costs and the theory of supply. *Journal of Political Economy* 75, no. 3, 321–334.
- Lucas, R. E., 1972. Expectations and the neutrality of money. *Journal of Economic Theory* 4, no. 2, 103–124.
- Lucas, R. E., 1976. Econometric policy evaluation: A critique. *Carnegie-Rochester Conference Series on Public Policy* 1, no. 1, 19–46.
- Lucas, R. E., 2004. My keynesian education. In: M. De Vroey, K. Hoover (eds.). *The IS-LM Model: Its Rise, Fall and Strange Persistence*. Durham: Duke University Press.
- Lucas, R. E., 2007. Central banking: Is science replacing art? In: E. C. Bank (ed.). *Monetary Policy: A Journey from Theory to Practice*. ECB. 168–171.
- Lucas, R. E., 2009. In defence of the dismal science. *The Economist* August 8.
- Lundberg, E., 1930. Om begreppet ekonomisk jämvikt. *Ekonomisk Tidskrift* 32, no. tr. 1995: "On the Concept of Economic Equilibrium" in E. Lundberg, *Studies in Economic Instability and Change*, ed. by R. Henriksson, SNS förlag, Stockholm, pp. 13–47, pp. 133–160.
- Lundberg, E., 1937. *Studies in the Theory of Economic Expansion*. London: P.S. King.
- Mandelbrot, B. B., 2005. Parallel cartoons of fractal models of finance. *Annals of Finance* 1, no. 2, 179–192.
- Mankiw, G. N., 1985. Small menu costs and large business cycle: A macroeconomic model of monopoly. *Quarterly Journal of Economics* 100, 529–39.
- Mankiw, G. N., 1989. Real business cycle: a new keynesian perspective. *Journal of Economic Perspectives* 3, 79–91.
- Mankiw, G. N., Reis, R., 2003. Sticky information: A model of monetary nonneutrality. In: P. Aghion, R. Frydman, J. E. Stiglitz, M. Woodford (eds.). *Information and*

- Expectations in Modern Macroeconomic: in Honor of Edmund S. Phelps. Princeton: Princeton University Press. 64–86.
- Mankiw, G. N., Romer, D., 1991. *New Keynesian Economics*. Cambridge, Massachusetts: MIT Press.
- Mas-Colell, A., Whinston, M., Green, J., 1995. *Microeconomic Theory*. Oxford: Oxford University Press.
- Mazzocchi, R., 2006. Some open issues in the new neoclassical synthesis. Working Paper presented to the annual Pontignano Meeting .
- Mazzocchi, R., 2010. Beyond DSGE: a Macrodynamical Model with Intertemporal Coordination Failure. DEPFID Working Papers 02/2010, Department of Economic Policy, Finance and Development, University of Siena.
- Mazzocchi, R., 2012. Cumulative process, inflation expectations and macroeconomic imbalances. Mimeo, University of Trento.
- Mazzocchi, R., Tamborini, R., Trautwein, H. M., 2009. The Two Triangles: What did Wicksell and Keynes know about macroeconomics that modern economists don't (consider)? Discussion Paper 06/2009, Department of Economics, University of Trento.
- McCallum, B. T., 1981. Price level determinacy with an interest rate policy rule and rational expectations. *Journal of Monetary Economics* 8, no. 3, 319–329.
- McCallum, B. T., 1986. Some issues concerning interest rate pegging, price level indeterminacy, and the real bills doctrine. *Journal of Monetary Economics* 17, 135–160.
- McCallum, B. T., 1993. Discretion versus policy rules in practice. two critical points: A comment. *Carnegie-Rochester Conference Series on Public Policy* 39, 215–220.
- McCallum, B. T., 2010. Michael woodford's contribution to monetary economics. In: V. Wieland (ed.). *The Science and Practice of Monetary Policy Today*. Springer, Berlin.
- McCallum, B. T., Nelson, E., 1997. An optimizing is-lm specification for monetary policy and business cycle analysis. NBER Working Paper 5875.
- McCallum, B. T., Nelson, E., 1999. Performance of operational policy rules in a estimated semiclassical structural model. In: J. B. Taylor (ed.). *Monetary Policy Rules*. Chicago: University of Chicago Press. 15–56.

- Mésonnier, J., Renne, J., 2004. A time-varying natural rate of interest for the euro area. Banque de France working papers 115.
- Messori, M., 1996. *La Nuova Economia Keynesiana*. Bologna: Il Mulino.
- Mishkin, F. S., 2008. Globalization, macroeconomic performance and monetary policy. NBER Working Paper 13948.
- Myrdal, G., 1927. *Prisbildningsproblemet och föränderligheten*. Uppsala: Almqvist and Wiksells Förlag.
- Neiss, K., Nelson, E., 2001. The real interest rate gap as an inflation indicator. Bank of England working papers 130.
- Nelson, C. R., Plosser, C. I., 1982. Trends and random walks in macroeconomic time series : Some evidence and implications. *Journal of Monetary Economics* 10, no. 2, 139–162.
- Orphanides, A., 2003. The quest for prosperity without inflation. *Journal of Monetary Economics* 50, no. 3, 633–663.
- Orphanides, A., 2007. Taylor Rules. Finance and Economics Discussion Series 18, Board of Governors of the Federal Reserve System.
- Orphanides, A., Wieland, V., 2008. Economic projections and rules of thumb for monetary policy. *Federal Reserve Bank of St. Louis Review* 90, 307–324.
- Orphanides, A., Williams, J. C., 2002a. Imperfect knowledge, inflation expectations, and monetary policy. NBER Working Paper , no. 9884.
- Orphanides, A., Williams, J. C., 2002b. Robust monetary policy rules with unknown natural rates. *Brookings Papers on Economic Activity* 2, 63–118.
- Orphanides, A., Williams, J. C., 2006. Inflation targeting under imperfect knowledge. CEPR Discussion Paper Series 5664.
- Paez-Farrell, J., 2003. Endogenous capital in new keynesian models. Research Memorandum, University of Hull 39.
- Papademos, L., 2008. The role of money in the conduct of monetary policy. In: A. Beyer, L. Reichlin (eds.). *The Role of Money: Money and Monetary Policy in the Twenty-First Century*. ECB. 194–205.
- Patinkin, D., 1989. *Money, Interest and Prices: An Integration of Monetary and Value Theory*. Cambridge, Massachusetts: MIT Press, (Orig. pub. 1956) 2nd edn.

- Pesaran, M. H., Chudik, A., 2011. Aggregation in large dynamic panels. CESifo Working Paper Series 3346.
- Pesaran, M. H., Smith, R., 2011. Beyond the dsge straitjacket. Cambridge Working Paper in Economics 1138.
- Pigou, A. C., 1933. *The Theory of Unemployment*. London: MacMillan.
- Poole, W., 2007. Understanding the fed. Federal Reserve Bank of St. Louis Review January/February, 3–14.
- Prescott, E. C., 1986a. Response to a skeptic. Federal Reserve Bank of Minneapolis Quarterly 10, no. 4, 28–33.
- Prescott, E. C., 1986b. Theory ahead of business cycle measurement. Federal Reserve Bank of Minneapolis Quarterly Review 10, no. 4, 9–22.
- Primiceri, G., 2006. Why inflation rose and fell: Policy-makers beliefs and u.s. postwar stabilization policy. Quarterly Journal of Economics 121, 867–901.
- Rajan, R., 2005. Has financial development made the world riskier? In: Proceedings of the Jackson Hole Conference. Kansas City Fed.
- Ramsey, F., 1928. A mathematical theory of saving. Economic Journal 38, 543–559.
- Reifschneider, D., Williams, J. C., 2000. Three lessons for monetary policy in a low inflation era. Federal Reserve Bank of Boston Conference Series Federal Reserve Bank of Boston, 936–78.
- Rogers, C., 1989. *Money, Interest and Capital. A Study in the Foundation of Monetary Theory*. Cambridge: Cambridge University Press.
- Rogoff, K. S., 1985. The optimal degree of commitment to an intermediate monetary target. Quarterly Journal of Economics 100, no. 4, 1169–1189.
- Romer, D., 2000. Keynesian macroeconomics without the lm curve. Journal of Economic Perspectives 14, no. 2, 149–169.
- Rosenburg, J., 2007. Interpreting the Decline in Long-Term Interest Rate. Tech. rep., Board of Governors of the Federal Reserve System.
- Rotemberg, J., Woodford, M., 1997. An optimization-based econometric framework for the evaluation of monetary policy. NBER Macroeconomics Annual .
- Rudebusch, G., Svensson, L. E., 1999. Policy rule for inflation targeting. In: J. B.

- Taylor (ed.). *Monetary Policy Rules*. University of Chicago Press. 203–262.
- Rudebush, G. D., 2002. Term structure evidence on interest rate smoothing and monetary policy inertia. *Journal of Monetary Economics* 49, no. 6, 1161–1187.
- Sack, B., Wieland, V., 2000. Interest-rate smoothing and optimal monetary policy: a review of recent empirical evidence. *Journal of Economics and Business* 52, no. 1-2, 205–228.
- Samuelson, P. A., 1951. Principles and rules in modern fiscal policy: a neoclassical reformulation. In: H. Waitzman (ed.). *Money, Trade and Economic Growth: Essays in Honor of John Henry Williams*. Macmillan.
- Sargent, T. J., 1999. *The Conquest of American Inflation*. Princeton: Princeton University Press.
- Sargent, T. J., Wallace, N., 1975. Rational expectations, the optimal monetary instrument and the optimal money supply rule. *Journal of Political Economy* 83, no. 2, 241–54.
- Sbordone, A. M., 2002. Prices and unit labor costs: a new test of price stickiness. *Journal of Monetary Economics* 49, 265–292.
- Schmitt-Grohé, S., Uribe, M., 2004. Optimal simple and implementable monetary and fiscal rules. NBER Working Paper 10253.
- Sevillano, J., Simon, M., 2004. An empirical approximation of the natural rate of interest and potential growth. Banco de Espana Working Paper 416.
- Siklos, P., Wohar, M., 2004. Estimating taylor-type rules: An unbalanced regression? *Advances in Econometrics* 20, 239–276.
- Simons, H. C., 1936. Rules versus authority in monetary policy. *Journal of Political Economy* 44, 1–30.
- Sims, C., 1980. Macroeconomics and reality. *Econometrica* 48, no. 1, 1–48.
- Sims, C., 1998. Projecting policy effects with statistical models. *Revista de Analisis Economico* 3, 3–20.
- Sims, C., 2003. Implications of rational inattention. *Journal of Monetary Economics* 50, 665–690.
- Smets, F., Wouters, R., 2003. An estimated stochastic dynamic general equilibrium model of the euro area. *Journal of European Economic Association* 1, 1123–1175.

- Smith, P., Wickens, M., 2006. The new consensus in monetary policy: Is the nkm fit for the purpose of inflation targeting. Centre For Dynamic Macroeconomic Analysis, University of York, Conference Paper 10.
- Solow, R., 1956. A contribution to the theory of economic growth. *Quarterly Journal of Economics* 70, no. 1, 65–94.
- Sonnenschein, H., 1972. Market excess demand functions. *Econometrica* 40, no. 3, 549–563.
- Sonnenschein, H., 1973. Do walras' identity and continuity characterize the class of community excess demand functions? *Journal of Economic Theory* 6, no. 4, 345–354.
- Stadler, G., 1994. Real business cycle. *Journal of Economic Literature* 32, 1750–1783.
- Stiglitz, J. E., 1991. Alternative approaches to macroeconomics: Methodological issues and the new keynesian economics. NBER Working Paper 3580.
- Stock, J. H., Watson, M. W., 2002. Has the business cycle changed and why? NBER Macroeconomics Annual 17, no. 9127.
- Summers, L. H., 1986. Some skeptical observations on real business cycles theory. *Federal Reserve Bank of Minneapolis Quarterly Review* 10, 23–27.
- Sveen, T., Weinke, L., 2003. Inflation and output dynamics with firm-owned capital. Universitat Pompeu Fabra Working Paper 702.
- Sveen, T., Weinke, L., 2004. New perspectives on capital and sticky prices. Norges Bank Working Paper 3.
- Svensson, L. E., 1997. Inflation forecast targeting. implementing and monitoring inflation targets. *European Economic Review* 41, 1111–1147.
- Svensson, L. E., 2003. What is wrong with taylor rules? using judgment in monetary policy through targeting rules. *Journal of Economic Literature* 41, 426–477.
- Svensson, L. E., 2010. Inflation targeting. NBER Working Paper 16654.
- Takats, E., 2010. Ageing and asset prices. BIS Working Paper 318.
- Tamborini, R., 2006. Back to Wicksell? In search of the foundations of practical monetary policy. Working paper, Università degli Studi di Trento.
- Tamborini, R., 2010a. The macroeconomics of imperfect capital markets. whither

- saving-investment imbalances? In: E. Saltari, G. Calcagnini (eds.). *The Economics of Imperfect Markets*. Springer, Wien. 137–166.
- Tamborini, R., 2010b. Monetary policy with investment-saving imbalances. *Metroeconomica* 61, no. 3, 473–509.
- Tamborini, R., Trautwein, H. M., Mazzocchi, R., 2013. Wicksell, Keynes and the new neoclassical synthesis: What can we learn for monetary policy? mimeo, University of Trento .
- Taylor, J. B., 1979a. Estimation and control of a macroeconomic model with rational expectations. *Econometrica* 47, no. 5, 1267–1286.
- Taylor, J. B., 1979b. Staggered wage setting in a macro model. *American Economic Review* 69, 108–113.
- Taylor, J. B., 1980. Aggregate dynamics and staggered contracts. *Journal of Political Economy* 88, 1–23.
- Taylor, J. B., 1993. Discretion vs. policy rules in theory and practice. *Carnegie-Rochester Conference Series on Public Policy* 39, 195–214.
- Taylor, J. B., 2007. Housing and monetary policy. NBER Working Paper 13682.
- Taylor, J. B., 2010. Macroeconomic lessons from the great deviation. *NBER Macroeconomics Annual* 25, 387–395.
- Taylor, J. B., 2011. Historical evidence on the benefits of rules-based economic policies. Address before the Joint Luncheon Session of the *American Economic Association and the American Finance Association* Sheraton Denver Downtown Hotel, no. Denver, Colorado.
- Taylor, J. B., Williams, J. C., 2010. Simple and robust rules for monetary policy. *Federal Reserve Bank of St. Francisco Working Paper Series* 10.
- Thornton, D., 2012. Greenspan’s conundrum and the Fed’s ability to affect long-term yields. *Federal Reserve Bank of St. Louis Working Paper Series* 036A.
- Trautwein, H. M., 2006. How Permeable are the New Synthetics? On the Difficulty to Teaching Macroeconomics. mimeo, Carl Von Ossietzky Universitaet Oldenburg.
- Trautwein, H. M., Zouache, A., 2009. Natural rates in the new synthesis: Same old trouble? *Intervention - European Journal of Economics and Economic Policies* 6, no. 2, 207–225.

- Truman, E. M., 2003. *Inflation Targeting in the World Economy*. Washington, D.C.: Institute for International Economics.
- Turner, P., 2011. Is the long-term interest rate a policy victim, a policy variable or a policy lodestar? BIS Working Paper 367.
- Turner, P., 2013. Benign neglect of the long-term interest rate. BIS Working Paper 403.
- Uhlig, H., 1999. A toolkit for analyzing nonlinear dynamic stochastic models easily. In: R. Marimon, A. Scott (eds.). *Computational Methods for the Study of Dynamic Economies*. Oxford: Oxford University Press. 30–61.
- Uhlig, H., 2001. The role of national central banks and of different policy cultures. In: C. Wyplosz (ed.). *The impact of EMU on Europe and the developing countries*. Oxford University Press. chap. 4.
- Van der Ploeg, F., 2005. Back to Keynes? Discussion Paper 4897, CEPR.
- Watson, M., 1999. Explaining the increased variability of long-term interest rates. *Federal Reserve Bank of Richmond Economic Quarterly* 85, no. 4.
- Weber, A., 2006. The role of interest rates in theory and practice. how useful is the concept of the natural rate of interest for monetary policy. *BIS Review* 18, 1–10.
- Wicksell, K., 1898a. *Geldzins und Güterpreise. Eine Untersuchung über die den Tauschwert des Geldes bestimmenden Ursachen*. (tr. 1936: *Interest and Prices. A Study of the Causes Regulating the Value of Money*, Macmillan, London). Jena: Gustav Fischer.
- Wicksell, K., 1898b. The influence of the rate of interest on commodity prices. In: E. R. Lindahl (ed.). *Wicksell: Selected Papers in Economic Theory*. London, 1958.: Allen and Unwin.
- Wicksell, K., 1922. *Vorlesungen über Nationalökonomie, Band 2: Geld und Kredit*. Jena: Gustav Fischer.
- Woodford, M., 2001. The taylor rule and optimal monetary policy. *American Economic Review* 91, no. 2, 232–237.
- Woodford, M., 2003. *Interest and Prices. Foundations of a Theory of Monetary Policy*. Princeton: Princeton University Press.
- Woodford, M., 2004. Inflation and output dynamics with firm-specific investment.

Unpublished manuscript.

Woodford, M., 2005. Firm-specific capital and the new keynesian phillips curve. *International Journal of Central Banking* 1, no. 2, 1–46.

Woodford, M., 2009. Convergence in macroeconomics: Elements of the new synthesis. *American Economic Review: Macroeconomics* 1, 267–279.

Yellen, J. L., 2005. President's speech: Update in the us economy.

Yun, T., 1996. Nominal price rigidity, money supply endogeneity and business cycles. *Journal of Monetary Economics* 37, 345–370.