Endogenous Business Cycles and Hysteresis.
A Post-Keynesian, Agent-Based Approach

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General introduction

Since the *marginalist* revolution of the 19th century, mainstream economic theory has historically developed around the concept of "natural" equilibrium (Lang, 2009). By assuming that the economic structure remains utterly invariant, business cycles have always been analysed through a strict dichotomy between the demand side, which is supposed to be representative of what economists define as the "short run", and the supply side, which is supposed to represent the "long run" *centre of gravity*. To the extent that the supply side is strictly independent from the demand side, long lasting deviations of the economy from the original steady state are interpreted as the consequence of exogenous structural changes taking place directly in the supply side. In absence of such exogenous shifts, demand shock must necessary cancel out in the end, when the economy adjusts to the "natural" equilibrium, by leaving no trace on the structure of the economy.

This theoretical framework has been radically questioned in the 1980s, in the wake of the oil shocks and the consequential deflationary policies implemented in most European countries (Blanchard & Summers, 1986; Cross, 1987). The empirical evidence of a strong persistence of high rates of unemployment, despite the temporary nature of the shocks, suggested the need for a new macro-dynamic framework alternative to the *Natural Rate Hypothesis* (NRH). There were two macro elements at stake: the more complex relationship between demand and the supply side, which are supposed to influence each other; and the non-reversibility of the consequences of shocks on the structure of the economy, namely *hysteresis*.

Not surprisingly, the financial crisis that burst out in 2008 raised a new emphasis on this topic. The evidence of the long run damages caused by the meltdown in most European countries on one hand (Ball, 2014), and the inadequacy of the mainstream to account for these permanent losses of productive capacity on the other hand (Cross et al, 2012), confirmed the failure of the neoclassical paradigm of asymptotic stability to provide a convincing explanation of real-world macro-dynamics. In particular, a growing literature is putting forward the hypothesis that large and/or long lasting negative shocks, such as the 2008's financial crisis, leave a permanent scarce on the economy (Blanchard & Summers, 1986; Ball et al, 1999; Cerra & Saxena, 2008; Ball, 2009; Schettkat & Sun, 2009; Cross et al, 2012).

There is still no theoretical consensus as regards how demand shocks impact on long run trajectories, and which modelling strategies are most appropriate to represent *hysteresis*. In particular, there are two main frameworks to explain and analyze the permanent impact of transitory shocks. According to the first one, *hysteresis* relies on the concept of *unit/zero root persistence* (Blanchard & Summers, 1986; Ball et al, 1999; Kapadia, 2005; Lavoie, 2006; Ball, 2009; Schettkat & Sun, 2009; Fontana & Passarella, 2014; Kienzler & Schmid, 2014). In this framework, *hysteresis* implies an exceptional persistence in disequilibrium adjustment that can be properly represented by non-stationary processes. The mean reverting property of these models – when properly differentiated – is one of the main reasons of their success, since it allows working on systems of linear equations that are easily testable through standard linear econometrics techniques. Furthermore, when introduced into broader mainstream macroeconomic frameworks, these models of hysteresis substantially validate most of the policy implications that apply also to non-hysteretic systems, at least in the long run (Kapadia, 2005; Kienzler & Schmid, 2014).

An alternative approach consists of representing hysteresis as a source of *structural change* (Roed, 1997; Setterfield, 1998, 2008). By abandoning the mainstream dichotomy between strictly stationary processes, characterized by a deterministic trend and temporary deviations, and strictly non-stationary processes, characterized on the contrary by a stochastic trend, these approaches focus on the possibility that demand fluctuations trigger structural changes that permanently affect the long run trend. In this framework, hysteresis is no longer related to non-stationarity but, generally speaking, to *non-ergodicity*.

The model of *genuine* hysteresis is part of this broader class of non-ergodic processes. Firstly theorized by J.A. Ewing in the 19th century while studying the properties of ferric metals submitted to a process of magnetization and de-magnetization, genuine hysteresis is the consequence of *non-linear* and *discontinuous* adjustments at the micro level that generate non-ergodic aggregate dynamics (Cross, 1993B, 1994; Amable et al, 1994, 1995; Piscitelli et al, 2000). The model of genuine hysteresis provides a macro-dynamic framework alternative to the unit root approach that is able to fit with empirical time-series, and which is able to provide an alternative analysis of business cycles and growth paths. Indeed, since the statistical properties of this model are radically opposed to the statistical properties of both traditional asymptotically stable models and random walks, namely as regards mean reversion (De Peretti, 2007), proving the consistency of the model with empirical time-series allows to credibly reject the NRH in favour of a more general theory of hysteresis that does not necessary require non-stationarity. Despite the large explanatory power of the genuine hysteresis model, which fits with virtually all time series, either stationary or non stationary, there are no systematic attempts to introduce this framework into broader macroeconomic models in order to analyze the emergent policy conclusions. The aim of this thesis is to formally introduce *genuine* hysteresis into a Post Keynesian macroeconomic model in order to analyze the consequences and the emerging policy implications, on a set of macroeconomic aggregate variables, of introducing non-linearity and discontinuity in investment decisions. In particular, by referring to the theories of sunk costs effects (Arker & Blumer, 1985; Garland, 1990) and *coerced investments* (Crotty, 1993), it provides a plausible micro foundation for investment decisions that might explain how aggregate structural changes can emerge endogenously from the aggregation of multiple and heterogeneous discontinuous decisions at the micro level. Furthermore, by relaxing some of the standard assumptions of the model, it aims at generalizing the application and validity of the model to more complex frameworks.

The recent development of agent-based computational techniques (ACE hereafter) appears as the most appropriate methodological framework to integrate genuine hysteresis into broader macroeconomic models. In this approach, aggregate results *emerge* endogenously by the aggregation of multiple and heterogeneous micro behaviours that are fully decentralized and independent from equilibrium constraints (Fagiolo & Roventini, 2012). By simulating a sequence of interactions among multiple and heterogeneous agents, within a specific institutional framework that determines the nature and the intensity of such interactions, the agent-based sequential approach is characterized by a large degree of endogeneity that allows running a simultaneous analysis of both the micro-to-macro and the macro-to-micro properties of the model. Therefore, introducing the genuine hysteresis framework into a broader agent-based model allows performing an integrated analysis of business cycles and growth trajectories by taking into account the feedbacks mechanisms that run from aggregate outcomes to micro behaviours. Furthermore, it allows analyzing the impact of institutions and economic policies in an artificial economic environment characterized by discontinuity and non-linearity of investment decisions.

The thesis is organized as follows. Chapter 1 focuses on the macroeconomic debate about asymptotic stability, unit root persistence and structural changes. In the first part (section 1.1) it provides a literature review about the Natural rate of unemployment (NRU) and the Non-accelerating inflation rate of unemployment (NAIRU), by focusing particularly on the common properties of these models, namely the short run-long run dichotomy that follows from asymptotic stability and time-independence. In the second part (section 1.2) of the chapter we provide a literature review about the theoretical developments in mainstream macroeconomics, namely the NAIRU framework, in order to take the empirical evidence of unemployment persistence and path-dependence into account. In particular, this part focuses on multiple equilibria, supply-side time variance and unit root persistence, by analyzing the theoretical and epistemological implications of these frameworks on the short run-long run dichotomy. In the third and last part (section 1.3) of the chapter we develop a literature review of the different theories of hysteresis based on the concept of structural change, by focusing specifically on the model of *genuine* hysteresis with its macro-dynamic implications.

Chapter 2 is a simple application of the *genuine* model of hysteresis to a "new consensus" macroeconomic model (NCM). After recalling the literature on unit root persistence and introducing the literature on NCM models, the first part of the chapter (section 2.1) focuses on the existing literature on potential output hysteresis and the monetary policy implications in the NCM framework. When introducing unit root persistence in "new consensus" monetary models, although supply side transitory shocks have permanent effects demand shocks do cancel out if monetary authorities successfully target a fixed inflation rate and the market clearing *natural* rate of interest. The second part of the chapter (sections 2.2 and 2.3) develops a "new consensus" model with *genuine* hysteresis in order to show that discontinuous entry and exit decisions of firms imply the impossibility for a monetary authority that follows an inflation target to *systematically* prevent permanent potential output losses in the wake of transitory demand shocks. For instance, according to the initial state of the economy, the amplitude of shocks and the reactivity of the monetary authority, temporary shocks might imply a shift to a new equilibrium still characterized by steady inflation and a *natural* rate of interest, but producing a different level of equilibrium output. The last part of the chapter (section 2.5) concludes on macro-dynamic implications and policy conclusions. In this framework, for instance, there is no fixed point that can be considered as a *long run centre of gravity*, the equilibrium being fundamentally endogenous and unpredictable. Discretionary fiscal and monetary policies are necessary to push the economy towards more efficient trajectories.

Chapter 3 extends the model of chapter 2 in an agent-based framework by increasing the degree of decentralization and introducing capital accumulation decisions. For instance, the model of chapter 2 assumed a binary choice between entry and exit with a fixed capital stock. By referring to the Post-Keynesian/Kaleckian theory of investment and savings, this chapter develops a micro-founded model of growth and distribution characterized by multiple and heterogeneous firms that take independent and decentralized investment decisions. In he first part of the chapter (section 3.1), we introduce the contemporary debate within heterodox schools of thought as regards the long run endogeneity of the rate of capacity utilization and related properties, namely the paradoxes of costs and thrift (Rowthorn, 1981). The second part of the chapter (sections 3.2 and 3.3) develops a neo-Kaleckian model of growth with decentralized and discontinuous investment decisions and illustrates the main properties of the model, namely the long run validity of the paradoxes of costs and thrift; the long run influence of *animal spirits* on capital accumulation; the permanent effects of transitory shocks on the rate of growth. In particular, we show that, contrarily to standard *genuine* hysteresis models that assume an exogenous sequence of input shocks, this model provides an endogenous input that exhibits hysteresis in the wake of transitory shocks. The third part of the chapter (section 3.4) concludes on the economic and economic policy implications of the model, namely the endogeneity of the rates of capacity utilization, capital accumulation and unemployment in the long run and the recessionary effects of austerity policies as long as they impact on income distribution, on households' saving decisions and firms' animal spirits.

Chapter 4 extends the model of chapter 3 by further increasing the degree of decentralization and complexifying the macroeconomic structure. The first part of the chapter (section 4.1) introduces the debate on capacity adjustment and investment decisions in *Dynamic stochastic general equilibrium* (DSGE), *Real business cycle* (RBC) and *Agent-based* (AB) models, by focusing in particular on the way non-linear and discontinuous investment functions have been integrated in these frameworks and the underlying theory of sunk costs. This part of the chapter introduces a broader theory of sunk costs based on the concepts of *sunk costs effects* (Arkes & Blumer, 1985; Garland, 1990) and *coerced investments* (Crotty, 1993) in a theoretical framework characterized by a net separation between management and ownership (Crotty, 1993; Jensen, 1993; Schoenberger, 1994; Clark & Wrigley, 1997). The second part of the chapter (sections 4.2 and 4.3) develops an Agent-based, stock flow consistent (AB-SFC) model with sunk costs effects and coerced investments, and analyzes its economic and macro-dynamic properties. It is shown that, in this framework, fiscal and monetary regimes determine not only the amplitude of fluctuations but also the long run trajectories. In particular, restrictive fiscal and monetary policies dramatically increase the instability of the economy by triggering larger fluctuations and endogenous structural changes. Expansionary fiscal and monetary policies play on the contrary a successful countercyclical effect by smoothing the business cycle and reducing the risk of structural changes. The last part of the chapter (section 4.4) concludes on the policy implications and possible evolutions of the model. The end of the thesis is dedicated to concluding remarks.

1. Asymptotic stability, path-dependence and hysteresis. A literature review on macro-dynamic properties of macroeconomic modelling

1.1. The Natural rate hypothesis: a historical perspective

1.1.1. Homeostasis and asymptotic stability

The neoclassical paradigm, that can be considered today as the most influential in mainstream economics, was grounded on the explicit aim of substituting the political approach to economics with a more rigorous and scientific approach that was supposed to turn economics into a “hard” science and give her a prestige and a credibility that only the mathematical language could give (Lang, 2009). Largely influenced by the paradigm of Newtonian mechanics and the theory of the field of forces developed by James Clerk Maxwell and Michael Faraday, neoclassical economists found it convenient to analyse economic phenomena in terms of fields of forces, in particular by referring to the concepts of conservation of energy and homeostasis (see below). Comparing utility to gravitational attraction and potential energy, economic constraints to kinetic energy, market rigidities to frictions, availability of resources to velocity and heat, economic models were most of the time directly imported from hydraulics or mechanics. Not surprisingly, the PhD thesis of Irving Fischer concerned a hydrostatic model of water flowing used to demonstrate how the marginal utility of consumption and the marginal cost of production are brought into balance (Cross et al, 2009).

Homeostasis and conservation of energy – the key properties of the dominant paradigm of physics at that time- are at the roots of the neoclassical economic analysis. A system that possesses the property of homeostasis is a system that always returns to its *status quo ante* when it is hit by a shock. Homeostasis is guaranteed by the principle of conservation of energy, according to which the energy of a system is never lost whenever the system is perturbed from its state of rest. It follows that homeostasis and conservation of energy imply full reversibility: shocks cannot have permanent effects provided that the system always returns to the equilibrium prior to the shock without loss of energy. Consequently, the equilibrium is never affected by the cyclical fluctuations of the system.

The notion of *equilibrium* represents the main “organizing concept” of the neoclassical paradigm (Setterfield, 2010). The existence of an asymptotically stable equilibrium is a mathematical necessary condition in order to postulate the strict independence of the short run and the long run in economic models: to the extent that an asymptotically stable equilibrium exists, any disequilibrium must be considered as purely transitory because the system will *in the long run* endogenously converge to the equilibrium. Hence, homeostasis, conservation of energy and asymptotic stability are at the roots of the neoclassical steady state analysis, consisting of a long run independent and stable *real* growth path and short run cyclical *monetary* trajectories.

Although there is no consensus as regards whether the neoclassical economists were perfectly aware of the set of mathematical and philosophical properties they were automatically importing in economics, namely time-reversibility and path-independence, since the mathematical models used were grounded in the dominant homeostatic paradigm of physics it would have been impossible for them to avoid it. Therefore, if neoclassical time is linear and reversible is probably explainable by the dominant influence of the Maxwellian homeostatic and time-independent paradigm of physics (Lang, 2009).

1.1.2. The Natural rate of unemployment and its policy implications

The concept of *Natural* rate of unemployment (NRU) was first introduced by Friedman (1968). Since the aim was not to introduce an equilibrium rate of unemployment but rather to demonstrate the neutrality of monetary policy, the NRU was at that time just an intuition. Friedman (1968) defines the natural rate of unemployment as the unique rate that allows real wages to growing at a secular rate:

“At any moment of time, there is some level of unemployment which has the property that it is consistent with equilibrium in the structure of real wage rates. At that level of unemployment, real wage rates are tending on the average to rise at a “normal” secular rate, i.e., at a rate that can be indefinitely maintained so long as capital formation, technological improvements, etc., remain on their long-run trends” (Friedman, 1968, p. 8)

Any other level of employment must be interpreted as being the signal of an excess of demand or supply of labour that makes real wages growing at a rate incompatible with a steady state rate of growth:

"A lower level of unemployment is an indication that there is an excess demand for labor that will produce upward pressure on real wage rates. A higher level of unemployment is an indication that there is an excess supply of labor that will produce downward pressure on real wage rates" (ibid, p. 8)

The mechanism of convergence towards the *natural* equilibrium is related to the duality between nominal and real values: if unemployment is below the "natural" rate, prices will be growing faster than nominal wages, therefore real wages decline and labour demand increases. This situation cannot last forever since workers will sooner or later realize the loss of purchasing power and will react to the higher labour demand by asking for higher nominal wages, until demand and supply come back into balance and the equilibrium real wage is restored. Therefore, there is only one equilibrium rate of unemployment that reconciles labour demand and labour supply, and at that rate of unemployment nominal wages and prices will grow simultaneously, leaving real wages unaffected.

There are, however, some missing points and inconsistencies in Friedman's analysis that are probably at the roots of the ambiguity lying on this concept. The NRU is also, according to Friedman, the outcome of a "Walrasian system of general equilibrium equations, provided there is embedded in them the actual structural characteristics of the labour and commodity markets, including market imperfections, stochastic variability in demands and supplies, the costs of gathering information about job vacancies and labour availabilities, the costs of mobility and so on" (ibid. p. 8). It is not clear, however, what Friedman refers to when speaking about "market imperfections", and how the contradiction between a general equilibrium system *à la* Walras - which requires perfect competition and perfect flexibility of wages and prices - and the existence of "labour market imperfections" and "costs of gathering information" can be solved. Furthermore, as argued by Lang (2009), it is not clear whether this equilibrium rate of unemployment is nothing more than a theoretical tool to understand and analyse economic reality or an observable and measurable value that actually takes place in real world. According to Friedman:

"One problem is that it cannot [the monetary authority] know what the natural rate is. Unfortunately, we have as yet devised no method to estimate accurately and readily the natural rate of either interest or unemployment. And the "natural" rate will itself change from time. But the basic problem is that even if the monetary authority knew the "natural" rate, and attempted to peg the market rate at that level, it would not be led to a determinate policy. The "market" rate will vary from the natural rate for all sorts of reasons other than monetary policy" (ibid, p. 8).

What we know so far is that a *natural* rate of unemployment exists and it is determined by some supply side characteristics of the labour market, that it is the only one consistent with a steady state rate of growth of real wages, and that there exist some endogenous mechanisms of convergence, or gravitation, around this equilibrium rate of unemployment. It is not clear, however, how the characteristics of optimality related to a Walrasian system of equations is compatible with market imperfections, which market imperfections did Friedman refer to and how can the "natural" rate of unemployment be of interest for the policy makers. Some specific characteristics and properties of the NRU will be clarified by Friedman in his 1977 "Nobel" lecture (Friedman, 1977). As regards market imperfections, for example, the reference is made to "the effectiveness of the labour market, the extent of competition or monopoly, the barriers of encouragements to working in various occupations, and so on" (Friedman 1977, p. 458). More specifically, the *effectiveness of the labour market* would refer to the higher workers' mobility that tends to make experiencing higher average rates of unemployment, while the *barriers to encouragements to working* refer to the amount and the generosity of unemployment benefits that reduce the pressure on the unemployed to seek for a job. However, as stressed by Lang (2009), the inconsistency between a Walrasian perfect competition framework and labour market imperfections still holds, as well as the empirical indeterminacy of the NRU.

The first rigorous formalization of an equilibrium rate of unemployment exhibiting the same properties of the NRU could already be found in Phelps (1967), one year before Friedman's contribution. According to Phelps (and consistently with Friedman's analysis), the well known-trade off between unemployment and inflation introduced by Phillips is only static and consistent with null expectations of inflation. From a dynamic point of view this trade-off is only an illusion, since a constantly positive rate of inflation will be sooner or later anticipated by agents in the form of higher nominal wages, giving rise to a wage-price spiral that makes inflation accelerating until agents' inflation expectations stabilize at a higher level. Here, the real wage converges to its equilibrium level consistently with a given rate of unemployment representing the new equilibrium rate. Nominal wages and prices will now be growing at the same steady rate, and both unemployment and inflation remain stable. Note, however, that despite the unemployment rate does not change, the steady state rate of inflation will now be higher according to the inflation expectations of agents that stabilized at a higher level. For instance, the steady state rate of growth is consistent with a stable real wage, not necessarily with zero inflation. More precisely, the equilibrium rate of unemployment is "the unemployment rate at which the actual rate of inflation equals the expected rate of inflation so that the expected inflation rate remains unchanged" (Phelps, 1967, p. 255). The equilibrium rate of unemployment, according to Phelps' representation, is therefore an ineluctable fixed point that is achieved through the rationality of economic agents, who take their decisions in a way that is *ex post* consistent with a long term steady real wage. Furthermore, the model of Phelps represents a specific theoretic support for monetary authorities: it is not possible to affect a real quantity (i.e. unemployment) with a monetary variable (i.e. prices), therefore monetary policy can only temporary increase the employment rate above its equilibrium at the costs of higher inflation, but sooner or later it must converge towards the equilibrium rate, which is assumed to be independent on inflation. Since in the long run money wage flexibility always accommodate inflation, so as to keep the real wage constant and unemployment stable on its equilibrium level, a direct consequence is that "the only steady state Phillips curve is a vertical line intersecting the horizontal axis at u^* *(the equilibrium rate of unemployment)*" (Phelps, 1967, P. 256, footnote 1).

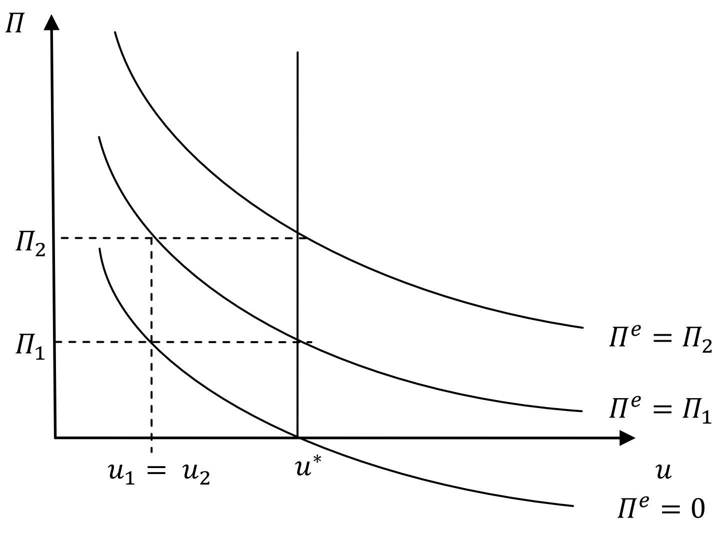

Figure 1.1: Phelps' vertical Phillips curve. The convex lines represent the (short run) Phillips curves, thus the (short run) trade-off between inflation (vertical axis) and unemployment (horizontal axis). The vertical line represents the long run stable rate of unemployment consistent with steady inflation

Although the Natural rate hypothesis (NRH) has been substantially accepted in mainstream economic theory, the model has been subjected to profound critiques as regards the market clearing properties of the equilibrium and, in particular, the choice of defining the equilibrium rate as "natural", thus responding to some ineluctable natural laws (Lang, 2009, p.

57; De Vincenti & Marchetti, 2005, p. 220). Friedman justified this choice by referring to the well known Wicksellian *natural* rate of growth. The term “natural” is used to distinguish real from monetary variables, the equilibrium rate of unemployment is *natural* because purely dependent on real variables and because it characterizes a steady state growth path (Friedman 1968, 1977). Moreover, the term “natural” should not be interpreted, according to Friedman, as immutable and independent from men, on the contrary “many of the market characteristics that determine its level are man-made and policy-made” (Friedman 1968, p. 9).

Nevertheless, the ambiguity of the term “natural”, together with the non-clarified Walrasian and non-Walrasian properties of the NRU, created the premises for the introduction of a new equilibrium rate of unemployment, the *Non Accelerating Inflation Rate of Unemployment*.

1.1.3. The Non-accelerating inflation rate of unemployment and its policy implications

First introduced by Modigliani & Papademos (1975) as the Non inflationary rate of unemployment (NIRU), the Non-accelerating inflation rate of unemployment (NAIRU) has been rigorously developed by Layard et al (1991), which is still today among the most influential academic works. This model keeps the general approach of the NRU, namely the existence of a unique equilibrium rate of unemployment that is consistent with steady inflation but independent on inflation itself. However, the introduction of monopolistic competition in the labour market (unions are supposed to bargain a real wage which is higher than the reservation wage of workers) makes the equilibrium between demand and supply consistent with involuntary unemployment: to the extent that the NRU is associated to fully voluntary unemployment, the NAIRU represents a special case in which the equilibrium real wage, because it is higher than the marginal disutility of work, does not clear the market (De Vincenti & Marchetti, 2005, p. 219).

In this framework there still exist some long/medium run endogenous mechanisms of disequilibrium adjustment which are related to the relationship between inflation and aggregate demand (Hein, 2005). When the rate of unemployment falls short of the NAIRU and the effective real wage is higher than the equilibrium real wage, inflation accelerates in order to keep up with nominal wage’s increases. Nevertheless, to the extent that the acceleration of inflation reduces aggregate demand because of the real balance effect, the fall in aggregate demand will push firms to adjust the quantity produced to the new level of demand until the lower labour demand raises unemployment up to the NAIRU. The opposite mechanism takes place if unemployment exceeds the NAIRU: in this case inflation decelerates and real aggregate demand increases until the rate of unemployment falls back to the steady inflation equilibrium.

According to NAIRU proponents, this new equilibrium rate of unemployment solves the contradictions of the NRU as regards the term “natural” and its market clearing properties: the NAIRU is an equilibrium characterized by monopolistic competition in the labour market and it is consistent therefore with involuntary unemployment (the equilibrium wage rate is higher than the marginal disutility of work). Unlike the NRU, it is not a market clearing *natural* equilibrium; it is an equilibrium consistent with *competing claims* of employers and employees. For instance, in this model unions bargain a non competitive real wage by applying a mark-up over the reservation wage (hence, over the marginal disutility of work), and firms set a non competitive price by applying a mark-up over the marginal productivity of labour. The NAIRU is an equilibrium in prices expectations (such as the NRU) and in the mark-ups: when the unemployment rate is equal to the NAIRU inflationary expectations turn out to be met (the expected real wage is equal *ex post* to the actual real wage), hence the mark-up applied *ex ante* by unions over the reservation wage is compatible *ex post* with the mark-up applied by firms over the marginal product of labour. This property of mark-ups compatibility explains why the NAIRU model is often referred to as the “battle of mark-ups” (Layard et al, 1991). Moreover, the NAIRU model adds a “Keynesian flavour” to the original Phelps/Friedman model: by introducing dynamic rigidities in the adjustment mechanism of wages and prices, the NAIRU becomes a long term equilibrium rate which is not necessarily met in the short and medium run, as long as aggregate demand fluctuations are not properly anticipated by employers and employees. Consequently, countercyclical demand policies can play a stabilizing role by accelerating the process of convergence towards the NAIRU.

Figure 1.3.1 reproduces the equilibrium rates of unemployment with perfectly competitive markets (NRU) and with non-competitive markets (NAIRU). The Price Real Wage (PRW) schedule represents the labour demand function in an economy characterized by imperfect competition, in which firms set their price by applying a mark-up on the marginal product of labour. The Bargained Real Wage (BRW) schedule represents the labour supply function in an economy characterized by imperfect competition, in which unions bargain the real wage by applying a mark-up on the reservation wage, which is equal to the marginal disutility of work.

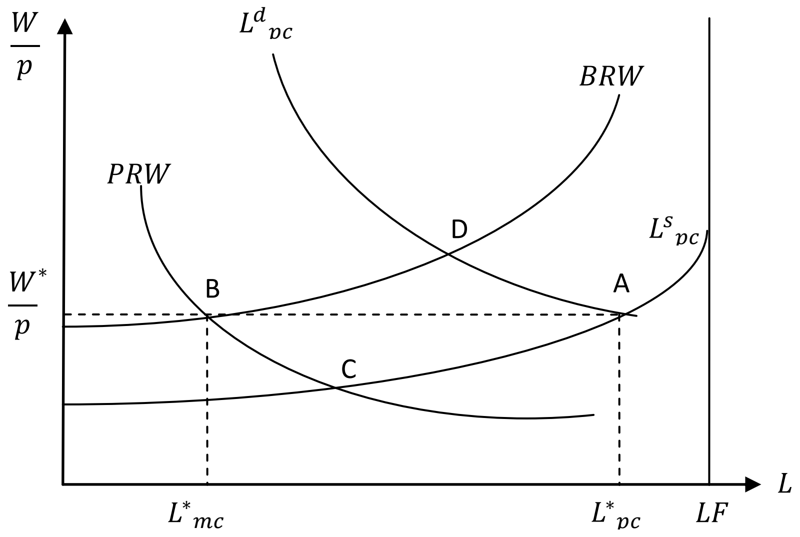

Figure 1.2: Employment and real wages in monopolistic competition with non competitive labour markets (Source: De Vincenti & Marchetti, 2005)

Figure 1.2 allows capturing the differences between the NRU and the NAIRU frameworks. The NRU represents a particular type of NAIRU that emerges when markets work *as if they were* in perfect competition. If markets were perfectly competitive the equilibrium real wage would be equal to the marginal disutility of work and to the marginal productivity of labour, and the rate of employment would be equal therefore to $L^*{}_{pc}$. Nevertheless, if the labour market is not perfectly competitive the equilibrium real wage lies constantly above the marginal disutility of work and below the marginal product of labour because of the mark-ups applied by unions and firms: the mark-up over the marginal productivity of labour implies that the price set by firms is higher than the price that would be set in a perfectly competitive environment, therefore the real wage is systematically below the marginal product of labour for each level of employment. The mark-up over the reservation wage (i.e. over the marginal disutility of work) implies that – given the expectations about future price - the nominal wage bargained by unions is higher than the nominal wage that each worker might be able to bargain individually in a perfect competition framework, consequently the real wage is systematically above the marginal disutility of work for each level of employment. The NAIRU is therefore an equilibrium that implies inefficiency in the degree of utilization of aggregate resources (namely labour) and involuntary unemployment.

The NAIRU is an *inefficient* rate of unemployment because the real wage is lower than the marginal productivity of labour; hence, it would be possible to hire a higher number of workers who are willing to work by increasing total productivity and total output. The measure of inefficiency is the *inefficiency gap*, which is the vertical distance between the labour demand schedule (i.e. the marginal productivity of labour) and the Price Real Wage (PRW) schedule, which is the labour demand function in the non competitive market. The consequence of the positive *inefficiency gap* is the waste of productive resources, which is measured by the difference between the level of employment at point A and the level of employment at point C.

The NAIRU is also an equilibrium that is consistent with involuntary unemployment. Indeed, if the labour market were perfectly competitive and the labour supply schedule reflected the marginal disutility of work, unemployment would be necessarily voluntary, since the unemployed would be those who are not willing to work at the equilibrium real wage because of a larger disutility of work. Nevertheless, because of the monopolistic behaviour of the representative union that applies a mark-up over the reservation wage, some of the unemployed are willing to work at the equilibrium real wage, since their marginal disutility of work is lower than the equilibrium real wage. The difference between the levels of employment in point C and in point B of figure 1.2 represents the measure of involuntary unemployment.

Therefore, the NAIRU represents a non market-clearing equilibrium rate of unemployment that is consistent with the mark-ups that monopolistic firms and unions apply to, respectively, the marginal productivity of labour and the marginal disutility of work. This distributive conflict or "battle of mark-ups" implies an inefficient equilibrium characterized by involuntary unemployment and waste of productive resources; moreover, it provides different explanations of the unemployment/inflation dichotomy and different policy receipts which are not fully equivalent (at least in the short/medium run) to standard explanations and policy recommendations provided by theories of perfect competition, namely the theory of the *natural* rate of unemployment. In the NRU framework, for instance, the equilibrium rate of unemployment, the absence of any obstacle to perfect competition implies that the *natural* rate of unemployment is a stable *centre of gravity*; therefore monetary policy is either useless or counterproductive to the extent that it crowds out the automatic adjustment mechanisms. In models based on imperfect competitions, on the other hand, a distinction has to be made between the long run and the short/medium run (De Vincenti & Marchetti, 2005).

From a short/medium run perspective the NAIRU proponents reject the neoclassical hypothesis of money neutrality. Although the NAIRU is as much an attractor as the NRU, they are generally sceptical concerning the hypothesis of full substitutability of production factors and flexibility of prices in the short/medium run. The existence of *frictions* in wage and price adjustments is often introduced into these models in order to take into account the possibility of a slow and sluggish adjustment to the long run equilibrium. Consequently, countercyclical monetary policies are effective in the short/medium run in order to stabilize more quickly the economy at the steady state. Suppose for example that degree of competition in the labour market lowers: firms raise the price mark-up and the PRW schedule shifts downwards. The equilibrium real wage falls and the NAIRU increases, therefore in absence of monetary interventions the system would converge slowly to the new equilibrium through inflationary pressures. If, however, the monetary authorities reduce the quantity of money immediately after the shock, they will stabilize aggregate demand downwards at the higher equilibrium rate of unemployment, avoiding a permanently higher inflation rate. Suppose now that the PRW shifts upwards because of a higher degree of competition in the goods market. In absence of monetary interventions the economy would undergo a transitory period of disinflation and higher rates of unemployment with respect to the new equilibrium. Monetary authority should thus increase the quantity of money in order to stabilize aggregate demand upwards and reducing quickly the rate of unemployment. Hence, monetary policy is a short/medium run effective tool to stabilize unemployment to the NAIRU, because these rigidities would disappear. In the long run, however, money is still neutral as in the NRU framework, since it cannot affect the equilibrium but only reduce the fluctuations around the equilibrium. Only micro economic policies aimed at increasing the degree of competition by liberalizing the goods and labour markets can push the NAIRU towards the NRU, which is the unique market clearing equilibrium (De Vincenti & Marchetti, 2005).

1.1.4. NRU Vs NAIRU: differences and similarities

Although some characteristics of the NAIRU are not explicitly mentioned in the NRU models of Friedman and Phelps, the debate is still open as regards whether the NRU and the NAIRU are substantially different. The ambiguity of Friedman specification concerning the NRU is probably at the roots of this controversy: is the NRU a voluntary rate of unemployment grounded on a Walrasian system of general equilibrium equations or did

Friedman explicitly mentioned market imperfections as a source of involuntary unemployment? According to Sawyer (1997) and De Vincenti & Marchetti (2005), the NAIRU and the NRU must be considered as two distinct frameworks: the NRU is a market clearing equilibrium that stands out from an analysis that assumes perfect competition, while the NAIRU is an equilibrium rate of unemployment which is explicitly grounded on imperfect competition and it is modelled as to achieve an equilibrium rate of unemployment that displays both inefficiency and involuntary unemployment. The NAIRU introduces therefore the distributive conflict as a possible source of inflation, which is not the case in the NRU where inflation is only a monetary phenomenon related to a pressure of effective demand above potential supply. Furthermore, assuming dynamic rigidities implies re-evaluating the role of monetary policy as a stimulus to effective demand and employment, consistently with the Keynesian framework: money is no longer neutral since it can stabilize the cycle around the trend and avoid unemployment to increase above the NAIRU.

Nevertheless, according to Lang (2009) and Ball (2009) there are no substantial differences in the two models, being the NRU and the NAIRU virtually synonyms (Ball, 2009, p. 4). Both the NRU and the NAIRU display time-reversibility and path-independence: wherever the system starts from, it will sooner or later converge to an equilibrium rate of unemployment which is to a larger extent exogenous. Asymptotic stability strongly relies on assumptions that are common to both the NAIRU and the NRU, namely that the appropriate equilibrium conditions include expectations being fulfilled and that the equilibrium is in the long run supply-side determined. In particular, according to Sawyer (1997):

1) Both models assume, in the long run, the validity of the Say's law. Both the NRU and the NAIRU are supply-side determined equilibrium rates of unemployment; shocks to aggregate demand can only perturb the system but they do not change the equilibrium; As a corollary, money is neutral in the long run.
2) The equilibrium is path-independent in both models. Small shocks or big recessions have a different impact only in the short run, because in the long run unemployment will converge back towards the NAIRU, without this latter being affected by the demand shock. This conclusion is strictly related to the hypothesis that demand shocks do not affect capital accumulation, since investments always accommodate savings, consistently with the Say's law;
3) The NAIRU and the NRU are both treated as unique equilibria. Even when multiplicity of equilibria is explicitly taken into account, "the estimation of the underlying equations and

the general discussion on the NAIRU proceed in a manner consistent with a unique equilibrium" (Sawyer, 1997, p. 3);

4) The NAIRU and the NRU are both strong attractors, in the sense that both appear in models built as to show asymptotic stability à la Lyapunov. If the system is perturbed in the aftermath of a demand shock, unemployment will return back precisely to the equilibrium, which is strictly exogenous with respect to demand;
5) Both the NRU and the NAIRU have "knife edge properties", in the sense that any disequilibrium level of unemployment is necessarily paid in terms of inflation or deflation. There cannot be any other level of unemployment for which inflation is stable, the NAIRU/NRU is the only unemployment level consistent with inflation stability.

Therefore, although the NRU and NAIRU frameworks are based on two different theories of competition and have different policy implications in a short/medium run horizon, the long run analysis of the economy is based on the same neoclassical "organizing concept", namely a supply-side determined and asymptotically stable *centre of gravity*. This neoclassical legacy, however, raises important epistemological and theoretical concerns about the importance of time and history, and the relevance of aggregate demand in the analysis of the long run.

1.1.5. Epistemological and theoretical remarks concerning the NAIRU and the NRU

Neither the NRU nor the NAIRU can be directly observed in the real world, they both represent theoretical concepts that can be at most estimated on the basis of some empirical data and theoretical assumptions. The fact that they cannot be observed does not, however, imply that they are of no use or interest for economic analysis. According to Sawyer (1997), in social sciences many, if not all, concepts are not directly observable or measurable, some of them do not even require to be observed and measured since they merely represent an abstraction useful to implement a theoretic analysis, and both the NAIRU and the NRU belong to this category. It could be of little interest to establish whether this equilibrium rate of unemployment exists and which value it takes, but it could be probably of a bigger interest to verify whether reality does actually conform to the predictions based on these models. Friedman (1953), for example, endorses such view and goes even further arguing that it cannot be of any importance the realism of a model, the most important property being its predictive power.

Conformity to reality, however, does not necessarily imply the theoretical validity of that concept. Even if reality did actually conform to the predictions of the NAIRU/NRU framework, this would not imply that the equilibrium rate of unemployment observed is indeed a NAIRU or a NRU: we cannot be content of verifying that reality conforms to the predictions of the NRU model in order to validate the NRH. In the DSGE models, for example, it is generally assumed that actual output naturally gravitates around its potential because of the real balance effect (Palumbo, 2008). The fact that actual output does actually display a cyclical tendency does not however imply that its average trend is necessarily a full-employment and full-capacity output. The same applies for the NAIRU/NRU: the cyclical fluctuation of the rate of unemployment around a given value does not imply that this average trend is necessary a NAIRU or a NRU, nor does it imply that this average trend be necessarily considered as a unique and absorbing equilibrium rate of unemployment. Indeed, in the economic literature we can find different models of NAIRU, every one possessing some different economic properties; hence, it would be difficult to decide which NAIRU is the correct one only by ensuring that reality conforms to the predictions of a general NAIRU model. To the extent that the NRU is considered as a particular NAIRU based on perfect competition, it would be as much difficult to decide whether the equilibrium rate of unemployment that conforms to reality is of a NAIRU or a NRU type. Conformity to reality and theoretical consistency are therefore complementary, rather than substitutes.

There is another characteristic of the NAIRU and NRU frameworks that is highly controversial: namely the assumption that demand always adjust to supply. This assumption is not independent on the full rationality hypothesis: to the extent that genuine uncertainty is ruled out and agents are assumed to rationally maximize a perfectly known environment, it is reasonable to assume that demand shocks do not have lasting effect on the equilibrium as long as agents keep on behaving as if the shock only consisted of a jump to a different initial position. Therefore, in the NAIRU/NRU frameworks the equilibrium rate of unemployment is purely supply-side determined, according to the implicit or explicit hypothesis that the potential growth path is fundamentally exogenous with respect to demand shocks. Full rationality, however, is not a sufficient condition to prove that the equilibrium is exogenous and asymptotically stable. Two further assumptions are at least required: on one hand, that there is always a level of demand able to absorb the entire production; on the other hand, that disequilibrium positions systematically adjust towards the independently determined level of supply consistent with full capacity and full employment.

The existence of a consistent demand for every level of supply is generally assumed by Say's law or by the real balance effect. Say's law, consistently with the classical paradigm, postulates that as long as money does not represent a commodity having a value *per se* but only represents an instrument to purchase real commodities, any commodity which is produced is necessarily sold and exchanged with other commodities. As a consequence, any supply creates an equal demand. Say's law, which was at the core of the well-known controversy between David Ricardo and Thomas Robert Malthus, had an extraordinary influence in the Keynesian critique of the classical theory of value. In particular, according to Ricardo effective demand could not have long lasting effects on aggregate supply because of Say's law, while Malthus rejected such law and advocated the idea that capital accumulation naturally reduces unproductive consumptions and, therefore, effective demand, causing a systematic excess of supply over demand (Kurz, 1994). Although imprecise as regards the causes of effective demand deficiencies, Malthus introduced the possibility that effective demand might fall short of effective supply by determining a long lasting period of under-utilization of capacity, a concept that Keynes developed in its *General Theory* by introducing radical uncertainty and preference for liquidity as violating conditions of Say's law. Malthus used for instance to define the Ricardian analysis in terms of "limiting principle", according to which the aggregate level of investments is *limited* by the level of aggregate savings consistent with full-employment and full-capacity utilization. However, the contingent state of the economy would depend on the "regulating principle", according to which a discrepancy between demand and supply might persist over a long period of time without necessarily adjusting towards the full-capacity supply barrier. In other words, Say's law implicitly postulates the asymptotic equality between the Malthusian "regulating" and "limiting" principles.

The debate between Friedman and Keynes is to some extent the same between Ricardo and Malthus. Indeed, Keynes did not argue specifically against the notion of a "natural rate" of unemployment but rather against the stability properties of such equilibrium:

"Keynes could have readily agreed with Friedman on the definition of the "natural rate of unemployment" (…) as corresponding to full employment (taking into account frictional and search unemployment) but differed in the major respect as to whether there was a strong feedback mechanism leading actual unemployment to the natural rate. Keynes would view the forces leading the actual rate of unemployment towards the "natural rate" as weak, and the achievement of the "natural rate" would require a high level of aggregate demand. In contrast, Friedman would view the adjustment of real wages in the face of excess supply of labour as the mechanism by which the unemployment moved rapidly to the "natural rate" (Sawyer, 1997, P. 4)

Full employment represents an upper bound which is theoretically unquestionable, but it reflects neither an equilibrium nor an average *state of rest*: to the extent that production does not automatically adjust to full-capacity supply in the aftermath of a demand shock, the new equilibrium can be persistently below the full-employment and full capacity barrier.

Alternatively to Say's law, the real balance effect postulates the adjustment of demand to supply through a wealth effect of inflation/deflation on consumptions demand: inflation (deflation) reduces (increases) the real value of money and, thereby, the real demand of goods. It is interesting to note that this mechanism works only under specific conditions. On one hand, there is the implicit assumption that lower prices and falling prices are equivalent: to the extent that the unemployment rate is above the NAIRU, prices are expected to fall and demand to increase, which is controversial in a real economy where expectations matter and investments are financially constrained (Sawyer, 1997). On the other hand, the effect of inflation on the real interest rate is essentially neglected: the increase (fall) in prices is only expected to decrease (increase) effective demand through a lower (higher) net wealth, ruling out pro-cyclical effects on investments through a fall (increase) of the real interest rate. Hence, the stability of the NAIRU implies that the real balance effect dominates the *real debt* effect, which implies in turn a propensity to consume for the renters higher than the propensity of investing out of retained profits for firms, which is unusual in a real economy (Hein, 2005). Therefore, the asymptotic stability of the NRU/NAIRU strongly relies on a set of controversial assumptions that are crucial to make the economic models consistent with homeostasis and time-reversibility. To the extent that these assumptions are proved not to hold, the whole model becomes extremely fragile and theoretically inconsistent. Hence, conformity to reality is not a sufficient condition to validate these models, since "if those models are on some relevant criteria judged to be unsound, then estimates and policy conclusions derived are seemly unsound" (Sawyer, 1997, p. 2).

1.2. Path-dependency, supply-side time variance and *hysteresis* in the mainstream approach

1.2.1. Time irreversibility and path-dependence: an empirical evidence

From an empirical point of view, the asymptotic stability property of the neoclassical paradigm has proved not to hold with the main stylized facts of the last decades. After the oil shocks and the deflationary policies of the 1980's, the unemployment rate in several European countries rather than showing a convergence towards an independent and predetermined NRU, as suggested by the theoretical models, displayed a growing trend that did not seem to be only temporary (Ball et al, 1999; Ball, 2009). The same applies in several Latin American countries in the late 40 years, where unemployment does not show any divergence-convergence pattern (Ball et al, 2011). Cerra & Saxena (2008) analyse the impact of financial and political crises in a set of 190 countries in the period 1970-2000 and show that when a crisis has occurred, the output losses have been permanent. In particular, according to their analysis, the negative effects of recessions are so persistent that only 1 percentage point of the deepest outcome loss is regained by 10 years after the crises. That is, economic recovery is simply a myth. As it appears in figure 1.3., when countries are hit by a recession we observe two possible scenarios: either the level of output falls although the rate of growth does not exhibit any long run damage, as it is the case for Korea and Chile, or the level of output and the rate of growth permanently shift downwards, as it is the case of all other countries. More recently, Ball (2014) analysed the consequences of the 2008 recession in Europe and had the same results: in most European countries the recession has not been merely temporary, potential output being permanently damaged. Figures 1.4 and 1.5 show indeed that in most European countries actual GDP and GDP growth (the full lines) exhibit a permanent downwards shift, therefore *post-crises* estimates of potential output growth (dashed lines) lie below the *pre-crises* estimates (the dotted lines).

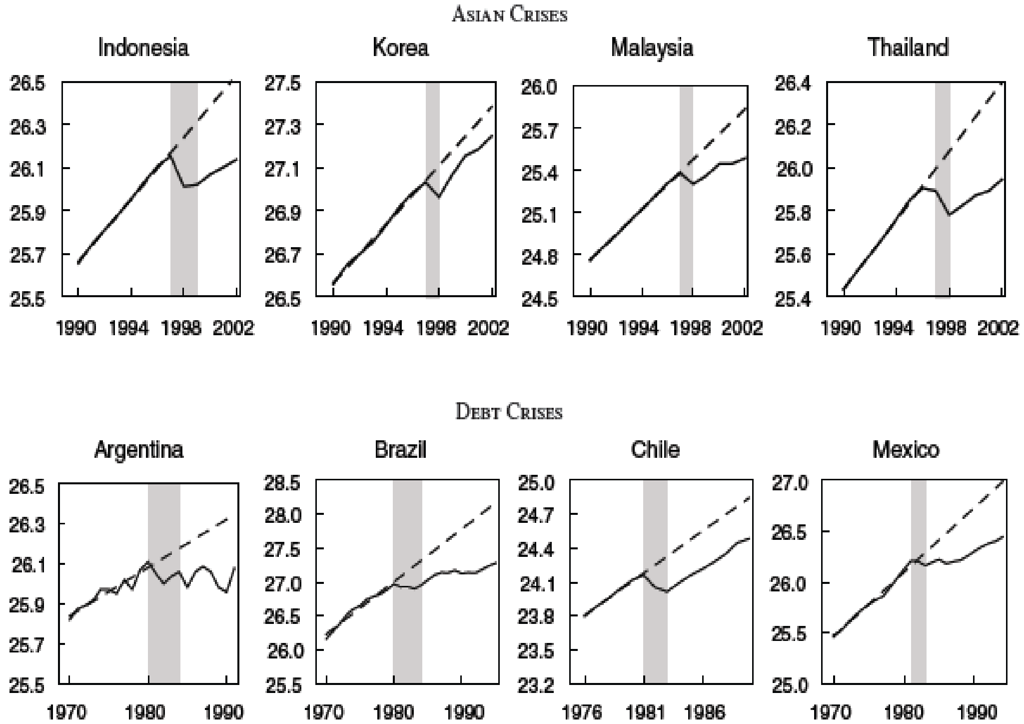

Figure 1.3: permanent output losses in the wake of strong meltdowns. The grey band represents the recession's duration, full lines represent the log of actual GDP (in the vertical axis) and dotted lines represent the linear initial long run trend of GDP (in the vertical axis). Source: Cerra & Saxena, 2008

Not surprisingly, some econometric studies find that the equilibrium rate of unemployment cannot be explained only by supply-side variables. Stockhammer & Sturn (2012) find no significance of the labour market institutional variables in explaining NAIRU estimates. Ball et al (1999) argue that labour market variables alone cannot explain the dynamic trend in the equilibrium rate of unemployment. Jackman et al (1996) also argue that labour market variables cannot explain the equilibrium rate of unemployment but merely some persistence patterns. It seems, therefore, that standard NRU and the NAIRU frameworks based on asymptotic stability cannot explain unemployment dynamics if they only focus on labour market institutional variables, including unemployment subsidy duration, employment protection and welfare policies. There is an important demand component in long run equilibria that might explain a large part of unemployment's variation and persistence.

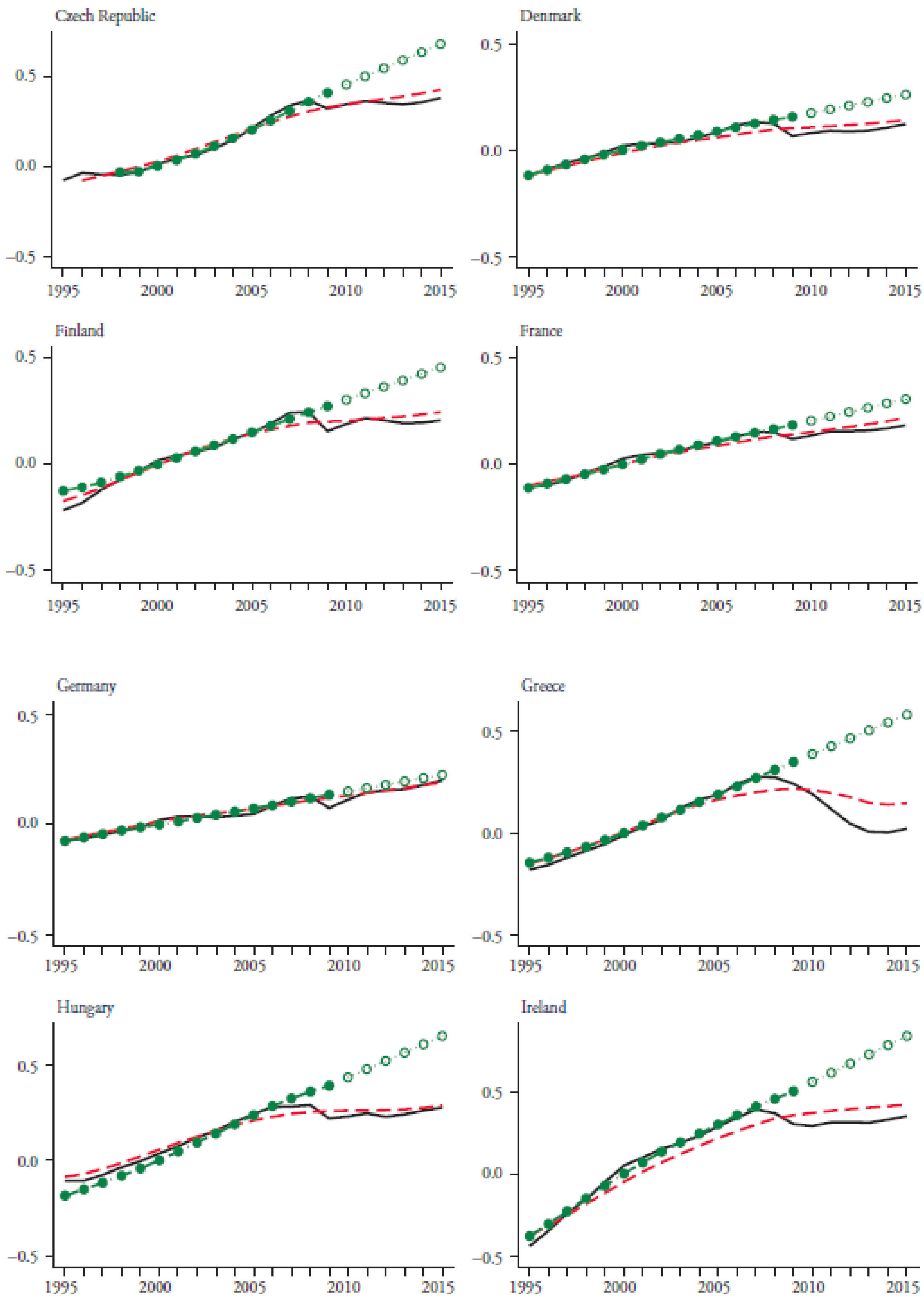

Figure 1.4: examples of permanent output losses in the wage of the 2008's Great Recession in a sample of European countries. (Source: Ball, 2014)

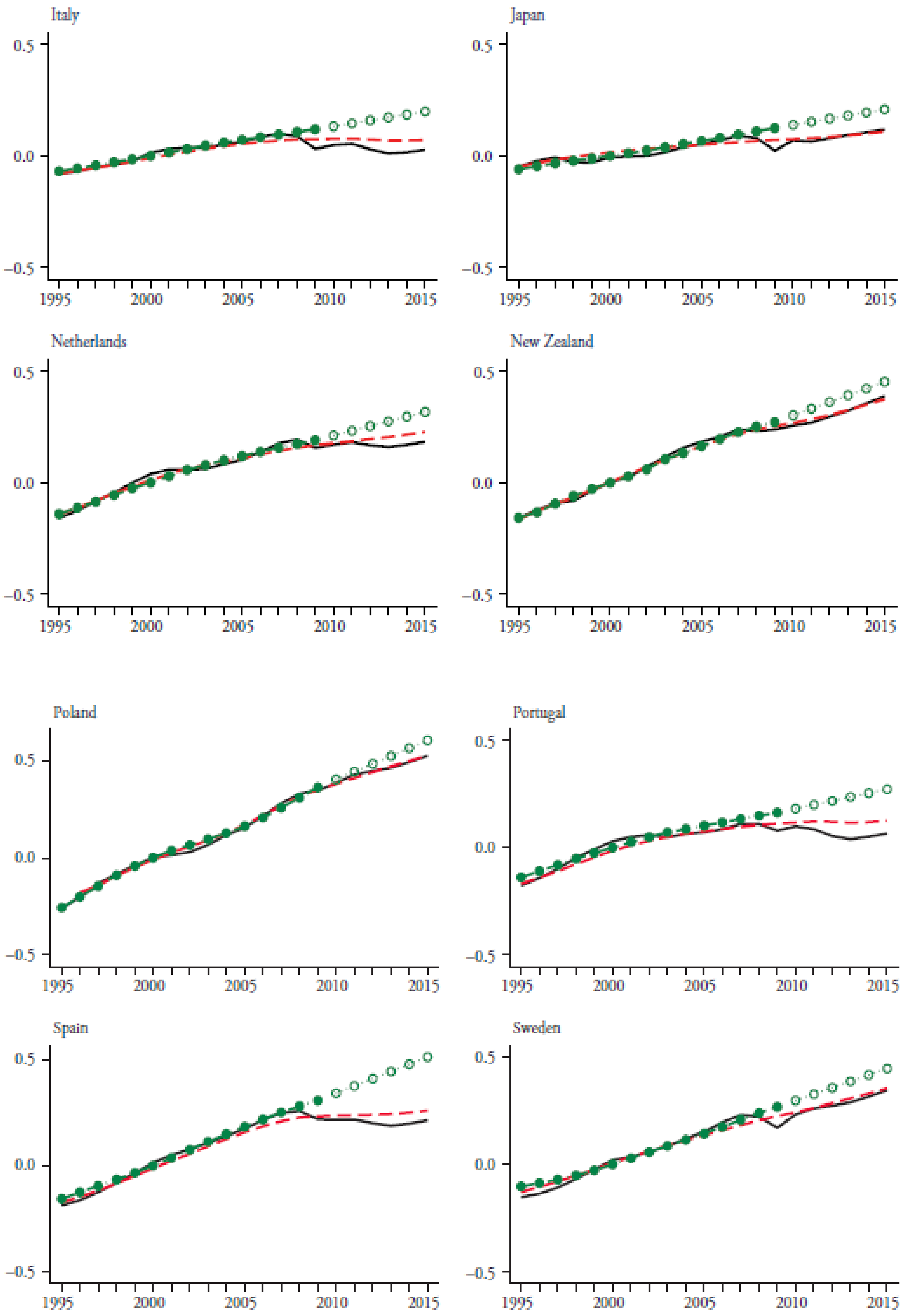

Figure 1.5: examples of permanent output losses in the wage of the 2008's Great Recession in a sample of countries. (Source: Ball, 2014)

1.2.2. Supply side shocks, equilibrium multiplicity and hysteresis

During the 1970s and the 1980s, the sudden rise in unemployment appeared fundamentally inconsistent with the long term vertical Phillips curve predicted by Friedman (1968) and Phelps (1967). In his Nobel lecture, Friedman explained this non-vertical Phillips curve as a transitory phase from a short run negatively sloped Phillips curve with zero inflationary expectations to a long run vertical Phillips curve with expectations of positive inflation, arguing that this transitory phase might last for a long time, "quinquennia or decades" (Friedman, 1977). According to Friedman (1977), what accounted for the temporary increase in unemployment despite the increase in inflation was the increasing price volatility and uncertainty that prevented agents from extracting the good signals from the market by creating disturbances in the process of adjustment of long run expectations. Hence, by deciding to suddenly lower inflation through deflationary policies, monetary authorities could not prevent unemployment to rise because of the higher volatility of prices and the sudden reverse to a new steady inflation regime. The consequence is a medium run Phillips curve being substantially negatively sloped, with lower inflation accompanied by higher unemployment. In other words, the Friedman's long run vertical Phillips curve is a very long run equilibrium that holds as soon as the following conditions are eventually met: 1) the rate of inflation is symmetrically volatile with respect to high or low levels of inflation; 2) relative prices are free to adjust symmetrically with respect to inflation; 3) contracts can be freely indexed to the new levels of inflation (Cross, 1984). The positively or negatively sloped medium run Phillips curves are therefore only a transitory phase triggered by higher uncertainty and prices volatility. As soon as inflation stabilizes and the three conditions are met, unemployment will thus converge towards its "natural" level, consistently with the long run vertical Phillips curve postulated by the (NRH). Although the deflationary policies implemented in the 1980s in most of the European countries did actually make unemployment increase, consistently with Friedman's predictions about a transitory negatively sloped Phillips curve, this growing trend did not seem to revert as the inflationary pressure fell, and the unemployment rate permanently stabilized at a higher level. In order to explain the time variance of the equilibrium rate of unemployment without rejecting the NAIRU framework, we can distinguish three main theoretical approaches.

The first approach consisted of introducing the possibility of a multiplicity of short/medium run equilibria characterized by path-dependence (Layard et al, 1991; Jackman et al, 1996; Gordon, 1997, 1998; Richardson et al, 2000; Ball & Mankiw, 2002;). Persistence of unemployment far from the long run steady state is explained by exogenous cost-push shocks and by the structure of labour market institutions, namely the length and generosity of unemployment benefits, the strength of employment protection legislation and the existence of minimum wages that prevent unemployment to adjust towards the long run NAIRU. By defining the short-run NAIRU as the level of unemployment consistent with steady inflation *in the current times*, supply-side cost-push shocks and labour market rigidities might explain the possibility to observe steady inflation and involuntary unemployment in the short/medium run (Cross & Lang, 2011). Nevertheless, as soon as cost-push shocks cancel out, involuntary unemployed must exert a downward pressure on real wages until unemployment adjusts to the unique long-run NAIRU. Involuntary unemployment therefore can only be a transitory phase characterized by real wage rigidity.

The second approach, which complements the first one, consisted of introducing the possibility of exogenous structural changes in the "time-varying NAIRU" (Gordon, 1997, 1998; Richardson et al, 2000; Ball & Mankiw, 2002)[1]. To the extent that exogenous structural changes, namely technological and labour market institutional shocks[2], affect the long-run NAIRU, the equilibrium can vary across time. In this framework, long run NAIRU's fluctuations are still explained by looking at the supply-side, demand plays no role on equilibrium conditions in the long run. In other words, the time-varying NAIRU does not tackle the stability and determinacy properties of the equilibrium in the wake of demand shocks, but rather its uniqueness across time (Setterfield, 2008).

The third approach to unemployment persistence, that developed parallel to the equilibrium multiplicity and the time-varying NAIRU theories, was proposed first by Phelps (1972) and then formalized by Blanchard & Summers (1986) by referring to the concept of *hysteresis*. In contrast to the long run vertical Phillips curve hypothesis that postulates the independence of the equilibrium rate of unemployment from inflation, Phelps (1972) had already introduced, on a purely theoretical ground, the possibility that a fall in the steady rate of inflation might increase not only actual unemployment but also its equilibrium rate. Generally speaking, the long run Phillips curve in Phelps (1972) is rather symmetric and

[1] This approach is fully consistent and complementary with the equilibrium multiplicity approach. For instance, models of time-varying NAIRU explain contemporarily short/medium run multiplicity by introducing cost-push exogenous shocks, and long run time-variance by introducing exogenous structural changes.
[2] Ball & Mankiw (2002) review a series of possible causes affecting the long run NAIRU, namely globalization, job market institutions and productivity acceleration.

negatively sloped: a fall or increase in the unemployment rate, caused by, respectively, an increase or fall in the rate of inflation, can permanently change some characteristics of the labour market in a way consistent with, respectively, a permanent reduction or increase in the NRU. Phelps' argument run as follows: when inflation decreases and workers experience a temporary increase in the rate of unemployment, the new equilibrium rate of unemployment that emerges when inflation stabilizes is not necessarily the same as before but will rather be higher, since unemployment implies a loss of skills and productivity that permanently changes the equilibrium conditions. Moreover, to the extent that employers perceive the unemployed as less productive and not employable, it becomes harder for the unemployed to find a new work position. A second mechanism that, according to Phelps, might imply a permanent shift of the NRU is the change in the structure of real wages when a temporary variation of employment leads to a permanent variation in the rate of unionization. These two mechanisms, that Blanchard & Summers (1986) formalized later on, are at the roots of the modern mainstream theory of *hysteresis*.

Although the term hysteresis came into a broader use in economics with Phelps (1972) and Blanchard & Summers (1986), traces of a *hysteretic* reasoning in economics go back to the classical economists. In particular, according to Marshall in its “Principles of Political Economy”:

"if the normal production of a commodity increases and afterwards again diminishes to its old amount, the demand price and supply price are not likely to return, as the pure theory suggests they will, to their old positions for that amount" (Marshall, 1890, pp. 425-26, cited in Cross, 1993)

Nicholas Kaldor, John Maynard Keynes, Joseph Schumpter, James Tobin and Nicholas Georgescu-Roegen also referred improperly to *hysteresis* to put forward the possibility that changes in a given input variable have persistent effects on another output variable, without however explicitly referring to the works of J.A. Ewing, who first introduced the concept of hysteresis in Physics in the late 19th century (Cross, 1993). Hysteresis is a term that was coined by the physicist J.A Ewing, who discovered an interesting property of metals when submitted to a demagnetizing and then re-magnetizing force: their field of force permanently changes, inconsistently with the Maxwellian paradigm of homeostasis (Amable et al, 1993; Lang, 2009). What Phelps (1972) and, in particular, Blanchard & Summers (1986) call hysteresis is actually a generic form of path-dependence that implies an extreme instability of the equilibrium rate of unemployment in the wake of demand shocks, without necessary exhibiting the main dynamic properties of the original model of hysteresis. In particular, under the influence of the seminal paper by Nelson & Plosser (1982), hysteresis has been associated to the existence of a unit root in the wage-price spiral, which generates a continuum of steady state rates of unemployment instead of a unique, asymptotically stable long run NAIRU.

1.2.3. Hysteresis as unit-root persistence

1.2.3.1. Epistemological assumptions

The origins of the unit-root models of hysteresis are in the seminal paper by Nelson & Plosser (1982), who analyzed the statistical properties of a set of time-series about unemployment and output to conclude that non-stationary, random walk models explain real trajectories better than standard stationary models. This empirical result was not neutral from a theoretical point of view: if stationary model could allow representing growth and fluctuations as mutually independent, random walk models are by definition non-stationary, therefore they are not mean-reverting unless properly differentiated (see section 1.2.4). Consequently, if real trajectories follow a random walk process, traditional models that distinguish between a long run deterministic trend and short run stochastic deviations lose their empirical relevance, since temporary shocks are no longer neutral on the equilibrium.

Based on their empirical results, Nelson & Plosser (1982) conclude about the necessity to develop integrated models of business cycles and growth trends in which short run stochastic fluctuations determine the long run trajectory. Blanchard & Summers (1986), who introduce hysteresis as “the possibility that increases in unemployment have a direct impact on the “natural” rate of unemployment” (ibid. p. 15) and then define it as “a very high dependence of unemployment on past unemployment” (ibid. p. 17), clearly go in the direction suggested by Nelson & Plosser (1982). By using hysteresis and path-dependence roughly as synonyms, the authors argue that “a dynamic system is said to exhibit hysteresis if it has at least one eigenvalue equal to zero (unity, if specified in discrete time)” (ibid. p. 17). NRU and hysteresis are therefore represented as two different and, to some extent, opposed frameworks, respectively a stationary/path-independent and a non-stationary/path-dependent one. In other words, hysteresis is a form of path-dependence, based on the existence of a unit root, which implies a radical violation of asymptotic stability and stationarity, the two main properties that characterize the NRU framework[3]. The term *hysteresis* has been largely used in the wake of Blanchard & Summers (1986) to define non-stationary processes that exhibit a unit root.

1.2.3.2. Theoretical models of hysteresis

According to Blanchard & Summers (1986), the sources of hysteresis in unemployment are in the real wage bargaining process. In particular, long-term unemployment is supposed to hamper real wages flexibility through virtually two main channels, the insider-outsider conflict and human capital accumulation. According to the insider-outsider theory (Lindbeck & Snower, 1986), to the extent that unions' members are the employed, that is “the insiders”, and that they are able to organize in order to prevent the outsiders from exerting a downward pressure on wages, changes in the rate of employment have no impact on the equilibrium real wage. Consequently, an adverse transitory economic shock that raises unemployment can imply a permanent shift in the labour supply schedule instead of a downward pressure in the real wage, by making unemployment structural. A different, but compatible, mechanism explaining a permanent shift in the labour supply schedule relies on human capital deterioration. The intuition is that long-term unemployed, because of their prolonged inactivity, lose their skills and their working abilities, and to the extent that firms are reticent to employ them, early retirements and discouragement would reduce the labour force and increase the rate of unemployment consistent with steady inflation. Note that human capital deterioration is not necessary to explain the reluctance of firm to hire long term unemployed as long as a “stigma” effect is on work (Lang, 2009): to the extent that firms perceive long term unemployed as less productive by associating long term unemployment to loss of skills and disaffection to work, long term unemployed would not be hired independently of the real human capital deterioration. Furthermore, the “stigma effect” also applies to the workers side by reducing their job search effort. When unemployment is low, the unemployed are stigmatized because they are considered not to be actively searching for a job, and social pressures push them to a higher job search effort. However, when unemployment is higher and mass unemployment appears as an involuntary phenomenon, the unemployed are less stigmatized and social pressures to increase the effort of job search are

[3] Note that *hysteresis*, in this framework, does not only imply the existence of a unit root, but it implies also the endogeneity of actual unemployment with respect to past realizations. For instance, also Gordon (1997) assumes a random walk process for the natural rate of unemployment; nevertheless Gordon’s model is not a model of hysteresis because erratic shocks are assumed to be exogenous and independent on unemployment.

lower. Hence, according to the "stigma effect" mechanism, long-term unemployment implies a shift in the NAIRU because long term unemployed are perceived by firms as less productive and because they do not actively search for a job. Unemployment hysteresis is therefore a consequence of the real wage rigidity with respect to employment variations, because of human capital deterioration, because of the "stigma" effect or because of workers resistance to real wage cuts. As a consequence, even though unemployment increases the real wage does not fall, and the level of unemployment that keeps the real wage (hence prices) constant, the NAIRU, becomes higher.

However interesting from a theoretical perspective, the insider-outsider theory of unemployment has been criticized for not being able to comply with the empirical evidence of low and falling unionisation rates in most European countries (Visser, 2006). In other words, there is no clear relationship between unionisation and unemployment hysteresis (Ball, 2009). Furthermore, the model relies on the assumption that unions only seek to maximize the insiders' utility, irrespective of the outsiders, which is not necessarily the case for most European countries where a large share of unions' members are outside the employed dependent labour force (Visser, 2006). A complementary argument concerning unemployment hysteresis, which calls into question social norms' rather than unions' power, focuses on the effect of *fairness* in wage bargain (Skott, 2004). Workers are assumed to bargain money wages on the basis of what they consider a *fair* real and relative wage. Firms, on their hand, know that if they accommodate the workers' demand, workers will be productive, while if they offer a wage which is lower than the *fair* one, workers will organize to reduce their overall productivity through shirking, striking, and so on. In order to obtain the highest level of productivity, firms always accommodate workers request and pay the *fair* wage. To the extent that the *fair* wage depends on previous real wage realizations, transitory shocks might have permanent effects: if a sustained economic growth increases the *fair* real wage, when unemployment suddenly raises because of a negative downturn firms keep on paying the *fair* wage in order to obtain the highest level of productivity. Consequently, the real wage does not fall and the level of unemployment consistent with real wage stability becomes higher.

By focusing on capital stock adjustments, Blanchard & Summers (1986) argued that a potential source of hysteresis might also depend on what they called the "physical capital story" (ibid, p.27). To the extent that capital and labour are *ex post* not substitutable, a negative shock affecting capital stock affects also overall employment. When the economy recovers from the shock and demand increases again, the lower capital stock implies inflationary pressures that slowdown and virtually neutralize the recovery. This theoretical explanation of hysteresis relying on capital shortage, however, does not appear as plausible from a neoclassical perspective to explain unemployment hysteresis. According to Blanchard & Summers (1986) in the long-run capital and labour are perfectly substitutable; therefore, an unexpected negative shock can cause unemployment to rise but in the long term, as firms can shift from a capital intensive to a labour intensive technique, there is no reason to believe in a capital stock constraint. Hence, to the extent that the real wage is flexible enough, the number of jobs created by new investments will compensate the number of jobs destroyed by the negative shock, and the NAIRU does not change. Consequently, for them, real wage rigidity rather than capital shortage is at the roots of unemployment persistence (Layard et al, 1991).

There is, however, a growing literature that rejects the assumption of perfect substitutability and underlines the crucial role of capital accumulation in determining both the equilibrium and the instability of unemployment. Econometric estimates of the elasticity of substitution provide a value which is closer to 0 rather than 1 (Rowthorn, 1999), suggesting that capital and labour are not substitutable but rather complementary. To the extent that the hypothesis of perfect substitutability of capital and labour is removed, capital shortage might explain a large share of unemployment (Van de Klundert & Van Schaik, 1990; Rowthorn, 1999; Arestis et al, 2007). The capital shortage theory has important economic implications. It can offer an important explanation of hysteresis by looking at the goods market rather than the labour market; Furthermore, by introducing complementarity in capital and labour, the long-term equilibrium rate of unemployment is no longer determined by the supply side only: it can be demand-led and path dependent. There are, however, some drawbacks in the capital shortage theory of hysteresis. According to Lang (2009), there is no reason to believe that in the long run labour be still constrained by a lower level of capital, since a sustained recovery accompanied by a higher expected demand should stimulate further investments and, therefore, higher employment. Hence, it is not clear what should prevent unemployment to regain the *ex ante* level when recovery takes over. In other words, it is not clear why a transitory shock should necessarily have a permanent effect.

According to Arestis et al (2007), what might generate hysteresis in the wake of capital shortage is the reaction of monetary authorities that target a steady inflation rate. The argument runs as follows: suppose a negative transitory shock caused, for example, by the rise in oil prices. This inflationary pressure exasperates the social conflict as regards who should carry the costs, and prices increase even further. In order to avoid hyperinflation, governments implement restrictive monetary policies, with negative consequences on capital accumulation and employment. A possible recovery would thus trigger a raise in inflation that would be hampered by a new restrictive monetary policy. Hence, an adverse transitory negative supply shock might imply a permanent loss of productive capacity that is policy induced (Fontana & Palacio-Vera, 2005). The two necessary conditions in order to have hysteresis in the wake of supply shocks are therefore a monetary policy reacting to inflation gaps and an endogenous mechanism of productive capacity adjustment in response to demand shocks.

Lavoie (2006) and Fontana & Passarella (2014) explain the endogeneity of productive capacity by focusing on the Harrodian concept of *natural* rate of growth (Leon-Ledesma & Thirlwall, 2002; Libanio, 2009). In particular, they argue that the *natural* rate of growth, which depends on the rate of growth of labour productivity and the rate of growth of the labour force, is endogenous to the actual rate of growth. Therefore, to the extent that a transitory positive shock to aggregate demand fosters new investments that raise output and labour productivity growth (Kaldor, 1957), the *natural* rate of growth will also increase. Nevertheless, according to Lavoie (1996) and Cassetti (2006), hysteresis might also be a consequence of adjusting the rate of capacity utilization rather than the rate of capital accumulation. To the extent that firms produce by running productive capacity at the *normal* rate, there might be hysteresis if what firms consider as *normal* depends on both historical conventions and past realizations. According to Robinson (1956), for instance, entrepreneurs tend to adapt their behaviour to subjective experience. In particular:

“Where fluctuations in output are expected and regarded as normal, the subjective normal-price may be calculated upon the basis of an average or standard rate of output, rather than capacity (...) Profits may exceed or fall short of the level on the basis of which the subjective normal prices were conceived. Then experience gradually modifies the views of entrepreneurs about what level of profit is obtainable, or what the average utilisation of plant is likely to be over its lifetime, and so reacts upon subjective–normal prices for the future” (Robinson, 1956, cited in Lavoie, 1996, pp. 127-128)

Hence, if because of a negative supply shock the rate of capacity utilization falls, firms might interpret this temporary change as a permanent change in market conditions and stabilize the rate of capacity utilization at a lower *normal* rate. Besides norms and conventions, however, the *normal* rate of capacity utilization might also depend on the existence of capital indivisibilities, economies of scale and multiplicity of production techniques (Nikiforos, 2013). Since productive capacity is by a large amount indivisible, firms might produce at a lower than *normal* rate of utilization when demand for their product is relatively low, especially if a firm has different production techniques implying a different utilization of fixed capital and different shifts. As a consequence, for a cost-minimizing firm, an increase in market demand might lead to an increase of the *desired* rate of capacity utilization as long as the returns to scale are increasing in the degree of utilization. In other words, the rate of capacity utilisation of a firm does not fluctuate around a fixed and exogenous *normal* rate, it rather fluctuates and stabilizes, under certain conditions, at different optimal or desired rates. Therefore, a temporary deviation from the norm is likely to change the norm itself.

Even though the different theories of hysteresis do not necessarily converge towards the same economic mechanisms (some relying on the wage bargaining process, some relying on capital scrapping or capital accumulation and some relying on the choice of the optimal degree of capacity utilization), most of these theories converge towards the same modelling technique. By referring to Setterfield (1998) we might say that stating (or asserting) the existence of hysteresis and providing a different theoretical explanation does not necessarily imply a different way of modelling hysteresis. What we observe, on the contrary, is that these different theories of hysteresis converged towards the unit/zero root approach.

1.2.3.3. Empirical models of unit-root persistence

The largest strand of the economic literature modelled hysteresis as a unit root process, or as a system of linear differential equations with at least one zero eigenvalue, is the path followed by (Blanchard & Summers, 1986; Van de Klundert & Van Schaik, 1990; Lavoie, 1996, 2006; Kapadia, 2005; Fontana & Palacio-Vera, 2005; Cassetti, 2006; Schoder, 2012; Fontana & Passarella, 2014; Kienzler & Schmid, 2014).

Define the equilibrium as:

$$u^* = \beta u^*_{t-1} + \gamma_t \tag{1}$$

γ_t is a stochastic shock with $E(\gamma_t) = 0$. If β<1, the unemployment time series is stationary and will converge to the unique and stable equilibrium

$$u^* = \frac{\gamma_t}{1-\beta} \tag{2}$$

If however β =1, the unemployment time series is a random walk, that is a non stationary time series with a unit root. In such a case, equation (1) will turn into

$$u^*_n = u^*_0 + \sum_{t=0}^{n} \gamma_t \quad (3)$$

Equation (3) represents an example of *hysteretic* process: the realizations of u^* depend on the whole series of past shocks that affected the economy. In other words, although u^* will, with probability 1, revert *sooner or later* to u^*_0, the economy might persistently fluctuate around u^*_0 for an unpredictable time horizon.

The zero root approach lies on the same assumption than the unit root approach, namely that hysteresis implies non stationarity. However, since the focus in no longer on a single autoregressive process but on a system of linear differential equations, non stationarity is contingent on the existence of at least one zero eigenvalue. To illustrate this approach we refer to Lavoie (2006). By assuming that the rate of growth of potential output is a function of the difference between real output and potential output:

$$\dot{g}_n = \phi(g - g_n) \quad (4)$$

And that real output growth is also a function of the difference between real output and potential output:

$$\dot{g} = \varphi(g_n - g) \quad (5)$$

Equations (4) and (5) can now be rewritten in matrix form:

$$\begin{bmatrix} \dot{g} \\ \dot{g_n} \end{bmatrix} = \begin{bmatrix} -\varphi & \varphi \\ \phi & -\phi \end{bmatrix} \begin{bmatrix} g \\ g_n \end{bmatrix} \quad (6)$$

The determinant of the Jacobian matrix is clearly null, since equations (4) and (5) are linearly dependent. This implies that the homogeneous system, with the time derivatives equal to zero, does not have a unique equilibrium but rather a continuum of equilibria. Furthermore, the trace of the Jacobian matrix, that is the sum of the main diagonal, is negative: Tr(J) $=-\varphi - \phi$. According to the Routh-Hurwitz conditions, a negative trace implies that equilibria are stable: if the system is perturbed from a given steady state, it will regain a different steady state. A positive trace, on the other hand, would imply that the continuum of equilibria is fully unstable: small perturbations imply a growing divergence from the steady state. If we compute the characteristic roots of the matrix we get at least one zero eigenvalue:

$$\lambda_{\frac{1}{2}} = \frac{-Tr(J) \pm \sqrt{Tr(J)^2 - 4|J|}}{2};$$

$$\lambda_1 = 0; \quad \lambda_2 = -Tr(J) = (\varphi + \phi)$$

The source of hysteresis lies on the existence of a zero eigenvalue in the system of linear differential equations. According to the unit root approach, on the other hand, the source of hysteresis lies in the existence of a unit root in the unemployment auto-regressive process, which takes the form of a random walk. Since the most important difference between the two approaches is the choice between difference or differential linear equations (Setterfield, 1998), it is interesting to focus on the similarities in terms of dynamic properties. First, unit root and zero root processes imply a full memory of the previous shocks. A random walk is by definition a non-stationary process that keeps the memory of all past shocks, as equation (3) clearly shows. In other words, the memory bank of the process is proportional and "elephantine": any shock, either small or big, will proportionally affect future equilibria. A second common characteristic of these two approaches is "full reversibility", which is associated with their linear structure. In both approaches, although a stochastic transitory shock implies a permanent change in the final equilibrium, cumulatively neutral shocks always imply cumulatively neutral changes. Since stochastic shocks are by construction cumulatively neutral, the effects on the equilibrium are cumulatively neutral as well, although characterized by a strong persistence. The third characteristic is that linear models of hysteresis are, if properly differentiated, mean reverting (De Peretti, 2007). For instance, if we rearrange equation (1) by assuming β =1we get

$$u^* - u^*_{t-1} = \Delta u^* = \gamma_t \qquad (7)$$

Δu^* is mean reverting. In other words, although the unemployment rate does not converge to a constant mean, unemployment variation is stationary around zero.

An alternative approach to unit root persistence characterizes hysteresis as a structural change (Setterfield, 2008). By assuming a non-linear relationship between shocks and equilibrium adjustments, a temporary shock might have a permanent effect by changing the structure of the system of equations that determine the long run equilibrium. In particular, based on the works of the Physicists J.A. Ewing and F. Preisach, Cross, (1993, 1994) and Amable et al (1993) introduced the *genuine* model of hysteresis as an alternative to unit root models in order to explain unemployment hysteresis. In this approach, hysteresis is no longer characterized by linear persistence but rather by endogenous structural changes.

1.3. Alternative approaches to hysteresis: cumulative non neutrality, discontinuous adjustments and structural change

1.3.1. Persistence Vs structural change

The random-walk approach suggested by Nelson & Plosser (1982) had a huge impact not only on theories of hysteresis but, generally speaking, on growth theories, especially in the Real Business Cycle (RBC) framework (Kydland & Prescott, 1982; King, Plosser & Rebelo, 1988; King & Rebelo, 2000). As long as transitory deviations affect the trend permanently, it is no longer possible to analyse business cycles by distinguishing between deterministic trends and stochastic fluctuations. By analysing the same time-series of Nelson & Plosser (1982), Perron (1989) argued that a simple model of structural change could also explain that same tendencies, without need to assume the existence of a unit root. Since then, several econometric analyses have confirmed that models of structural change are also able to perfectly fit with empirical data (Hansen, 2001). Papell et al (2000) analyzed the unemployment time series of a set of OECD countries and could reject the unit-root hypothesis for 10 out of 16 countries in favor of the alternative hypothesis of a single structural break. Arestis & Mariscal (1999) analyze the unemployment time series in a set of 26 OECD countries and find one to two structural breaks in each of the time series. Hence, they can reject the unit-root hypothesis for up to 22 out of 26 countries, in favor of a single or double structural change.

Distinguishing between random walks and alternative linear or non-linear models allows reaching radically different conclusions in terms of short run fluctuations and long run tendencies. Amable et al (2004) show that the non-linear model of "genuine" hysteresis (see section 1.3.3) can generate a non-stationary output that can be easily confused with a random walk. However, if properly differentiated, the random walk is mean reverting, while the non-linear model of "genuine" hysteresis is not (De Peretti, 2007). Consequently, empirical analysis showing that aggregate time series exhibit unit roots are not sufficient to argue in favour of modelling output and unemployment as random walks. Alternative theories of hysteresis that focus on structural changes would equally fit with empirical data, providing however a different characterization of the trend-cycle relationship, thus different economic and policy implications.

1.3.2. Hysteresis as a theory of structural change

A different approach, which is more general than the unit root one, characterizes hysteresis in terms of endogenous structural changes (Roed, 1997). Hysteresis implies the violation of the standard path-independent and stable framework: there is hysteresis when there is not convergence to an exogenously determined equilibrium rate. Hysteresis is characterized in this framework by endogenous structural changes that affect the main parameters of the economy and thereby the long run equilibrium. According to Roed, for instance, hysteresis needs not to be found in the specific properties of some variables but rather in the system of equations determining the equilibrium rate, in particular as regards the exogenous and the endogenous variables. Whereas in the standard NRU/NAIRU models the parameters can change only because of exogenous shocks, hysteresis implies that parameters can also change endogenously, according to the contingent movements of the system outside of the equilibrium. Generally speaking, suppose a function of this form (Roed, 1997):

$$u_t = f(U_{t-1}, y_t, x_t, X_{t-1}) \quad (8)$$

f(.) is a fixed function, U is a vector of past realizations of u, x is a vector of exogenous variables, X is a vector of past realizations of the exogenous variables x and y is the vector that captures the exogenous structural changes. According to Roed (1997), the equilibrium is path-independent and non-hysteretic if:

$$\lim_{t \to \infty} u_t = u(x, y) \quad (9)$$

That is, if unemployment depends on exogenous variables and exogenous structural changes only, it is time-independent and non-hysteretic. Hysteresis is defined as the violation of equation (9), hence as the equilibrium dependence on past realizations of u and x that generates *endogenous* structural changes.

The structural change approach to hysteresis appears to be more general than the unit/zero root approach: if on one hand this characterization of hysteresis can include unit root processes, it is also open to a broader spectrum of possible situations, including non-linear models of hysteresis. Furthermore, the existence of endogenous structural changes might rule out the hypothesis of a unique and stable long run exogenous equilibrium rate. In this sense it might represent a "falsification" of the standard NAIRU model (Lang, 2009, p. 115). However, this too broad definition includes any path-dependent dynamics, turning hysteresis into a synonym of path-dependence.

According to Setterfield (1998), however, hysteresis is a special case of path-dependence:

"hysteresis exists when the long-run or final value of a variable depends on the value of the variable in the past, by virtue of the influence of this past value on the current alleged exogenous variables, coefficients and structural equations which characterize the system that determines the variable" (ibid. p. 284).

Hysteresis is not just a matter of short-run disequilibrium: it is a violation of the long run homeostatic property of macro dynamic systems. Furthermore, hysteresis exists when "the cumulative impact on (...) the long run outcome of a system of movements along a prior disequilibrium adjustment path, is non zero" (ibid. p. 292), since it involves an "explicit structural change in the system that is determining long run outcomes" (ibid. p. 294). This definition of hysteresis as a disequilibrium adjustment process related to "cumulatively non neutral changes" clearly separates hysteresis from generic forms of path-dependence and multiplicity of equilibria. According to Setterfield (1998), hysteresis is a particular type of path dependence that emerges from the reconsideration of the asymptotic stability properties of the attractors. While systems with multiple equilibria generally imply the existence of a continuum of equilibria - some of whom still possessing the property of stability - depending on the initial position, hysteresis calls for a more radical uncertainty concerning not only the initial position but also the specific adjustment path:

"A hysteretic system may actively create its own set of final outcomes in the course of its evolution as a result of this structural change. (…) it may only be within our powers to identify these outcomes *ex post*, after they have actually been established. They need not exist *ex ante*, independently of the actual history of adjustments" (ibid, p. 294).

More precisely, in Setterfield (1998) hysteresis emerges consequently to "adjustment asymmetries". Let define

$$Z_t = f_t(X_{t-1}) \tag{10}$$

Let also assume that the variable X undertakes a cumulatively neutral change in the time interval [1,n]:

$$\Delta X = \sum_{t=1}^{n} \Delta X_t = 0 \tag{11}$$

According to Setterfield (1998), there is hysteresis as long as cumulatively neutral changes in X imply cumulatively non-neutral changes in Z:

$$\Delta Z = \sum_{i=1}^{n} f'_{i+1}(\Delta X_i) \neq 0 \tag{12}$$

Hysteresis is triggered by a cumulatively non-neutral change of Z caused by a cumulatively neutral change in X. From a mathematical point of view, cumulative non-neutrality is a consequence of *asymmetry* and non-linearity of $f'(.)$. Indeed, if Z were a linear function of X, cumulatively neutral changes of X would necessarily imply cumulatively neutral changes in Z. From an economic point of view, this "cumulative non neutrality" depends on *structural changes* that happen to the system of equations determining Z when the variable X is perturbed.

This characterization of hysteresis displays significant differences with respect to the unit root approach. First, the unit root approach requires non-stationarity by definition, while the "adjustment asymmetries" approach only requires asymmetric structural changes, which are virtually consistent with both stationary and non-stationary processes. In other words, this structural change approach does not necessarily require non-stationarity; it only requires non-ergodicity, which is a property consistent with stationarity (Grazzini, 2012). Second, the unit root approach only requires the knowledge of the starting point and the amplitude of the shock in order to determine the arrival point. In the "adjustment asymmetries" approach, on the other hand, uncertainty is not only related to the initial position and to the amplitude of the shock, but also to the structure of the long run outcome: the same initial position can lead to different and undetermined long run outcomes according to the amplitude and frequency of structural changes. Consequently, it is not possible to predict *ex ante* the final equilibrium as long as the set of information only includes the initial position (Setterfield, 1998, p. 293-294).

This approach differs also from the "endogenous structural change" one in terms of *lower* generality: hysteresis is no longer a synonym but a special case of path-dependence. Nevertheless, it gains in terms of generality with respect to the "genuine" hysteresis framework (see section 1.3.3.): for instance, if "genuine" hysteresis implies adjustment asymmetries, adjustment asymmetries do not necessarily imply "genuine" hysteresis. This definition of hysteresis includes a broader set of models that might not display the properties of "genuine" hysteresis, namely selective memory and *remanence*. Nevertheless, characterizing hysteresis as an "endogenous structural change" that emerges from "adjustment asymmetries" that bring about "cumulatively non-neutral changes" seems the most consistent approach when thinking of business cycles as cumulatively neutral fluctuations. Next section introduces the model of *genuine* hysteresis, which belongs to the larger family of models that exhibit adjustment asymmetries and endogenous structural changes.

1.3.3. Sunk costs, discontinuous adjustments and hysteresis: an endogenous structural change approach

J.A Ewing first coined the term hysteresis in the late 1881, when he noticed an unexpected property of ferric metals that did not revert to their original position after a complete cycle of magnetisation and demagnetisation. Indeed, at that time the dominant paradigm in Physics was the homeostatic system of equations of Maxwell, which assumed the return of the ferric metal to its previous state after the magnetising force had been removed (Cross, 1993; Lang, 2009). J.A. Ewing conducted the experiment at the macro level. Half a century later, the Hungarian physicist Preisach, who formalized the model of hysteresis, explained the micro-mechanism conducing to hysteresis. According to Preisach (1935), ferric metals are composed of micro elements named “hysterons”, or “hysteresis operators”, which respond to magnetisation according to two distinct critical values: the hysteron is either “up” or “down” according to whether the magnetising or demagnetising force is sufficiently high to trespass the relative threshold value. The important feature of ferric metals is the fact of being composed of multiple and heterogeneous micro particles, the hysterons, that respond discontinuously to the external magnetisation force. In 1989, the Russian mathematicians Krasnosel'skii and Pokrovskii, who were interested in generalizing this model to other scientific fields other than physics, formalized the mathematical properties of the Preisach model. Eventually, in 1991, the Ukrainian mathematician I. D. Mayergoyz developed an intuitive graphical method to represent the dynamic properties of hysteresis.

Hysteresis is a macro behaviour that emerges from the aggregation of multiple and heterogeneous elements, the hysterons. It has a micro (weak) and a macro (strong) representation: *weak* hysteresis denotes the hysteretic behaviour of each hysteron; *strong* hysteresis denotes the result of hysterons’ aggregation. To understand micro hysteresis it is necessary to investigate the structure of the hysterons, in particular as regards the way they respond to a magnetic shock. When a metal is subject to a magnetising force, the hysterons either magnetise or they do not, according to the amplitude of this force with respect to a couple of critical values: a lower critical value, say *b*, under which the hysteron is “down”; an upper critical value, say *a*, over which the hysteron is "up". The structure of each hysteron can be represented by the "non-ideal relay":

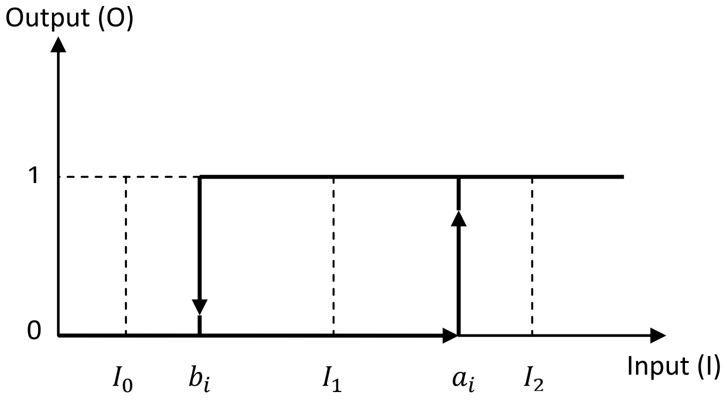

Figure 1.6: The non-ideal relay

The output is a binary variable equal to 0 (down) or 1 (up) on the basis of two switching values, *a* and *b*, and the input shock. If the hysteron is "down" and the input shock is sufficiently high to trespass the critical value *a*, the hysteron will switch to "up". If the hysteron is "up", in order to switch to "down" the input shock must be sufficiently negative to trespass *b*. If, however, the input shock is higher than *b* but lower than *a*, the hysteron will not change its state: if it was "down" it will stay "down", if it was "up" it will stay "up". Formally, if "O" stands for output and "I" stands for input, the set of possible outcomes is the following one:

$$O_{i,t} = \begin{cases} 1 \quad if \quad O_{i,t-1} = 1 \quad and \quad I_t > b_i \\ 1 \quad if \quad O_{i,t-1} = 0 \quad and \quad I_t > a_i \\ 0 \quad if \quad O_{i,t-1} = 0 \quad and \quad I_t < a_i \\ 0 \quad if \quad O_{i,t-1} = 1 \quad and \quad I_t < b_i \end{cases} \tag{13}$$

The input-output relationship is clearly non-linear, and it implies a discontinuous and asymmetric adjustment of output to input changes. Suppose for instance that the output variable at time *t* takes value 0 and the input variable is in between *a* and *b*, say on I_1. If suddenly the input variable increases above *a*, say on I_2, the output will switch to 1, but if at time *t+1* the input variable comes back to I_1, that is in between *a* and *b*, the output does not switch back to 0. Note, however, that the cumulative impact can also happen to be null with respect to the output variable, depending on the initial position. Suppose the initial output is 0 and the input variable is below *b*, say on I_0. As soon as the input variable increases above *a*, on I_2, and then comes back to I_0, the cumulatively neutral shock on input implies a cumulatively neutral effect on output.

These examples illustrated the properties of *weak* hysteresis: the amplitude of the input shock does not matter *per se,* since the memory bank of the process retains only the shocks that are able to make the output variable switching from one state to the other. A small shock that implies a switch from one state to the other will have longer lasting effects than a bigger shock that does not imply a switch of the output variable. There is not necessary proportionality between input shocks and output reactions. The three main properties of micro hysteresis that arise from non-linear and discontinuous adjustments are the following ones (Lang, 2009, p. 145):

1) The history of the system matters: the non-linear and discontinuous relationship between input and output makes the present state dependent on the extreme values of the past shocks.
2) There can be *remanence* if a cumulatively neutral input shock makes the output switching from one state to the other. This possibility depends on the specific shock; a cumulatively neutral input shock can imply a cumulatively neutral output shock.
3) *Remanence* does not depend necessarily on the amplitude of the shock, since there is no proportionality between input and output.

Strong hysteresis emerges from the aggregation of the multiple and heterogeneous *weakly* hysteretic behaviours, and can be represented graphically in the Mayergoiz's half plane diagram:

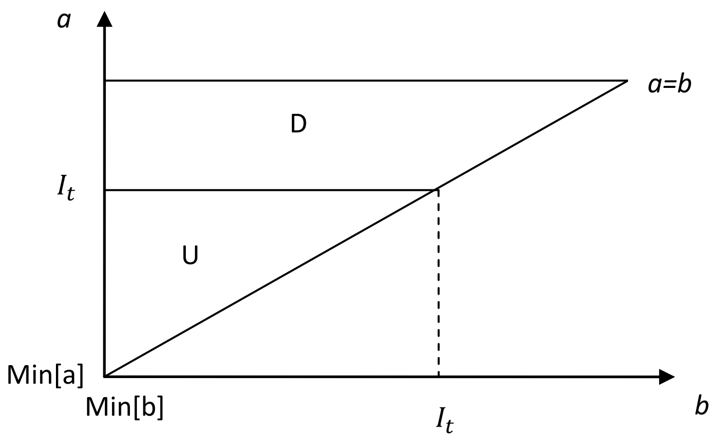

Figure 1.7: representation of the Mayergoiz's half-plane diagram. The origin corresponds to the lowest a and b thresholds.

The diagram in figure 1.7 is defined only in the upper half plane, since the critical value a is always, by definition, higher than the critical value b. Each point in the upper half plane represents a specific hysteron. The "U" area includes the hysterons that are "up", since $I_t > a_i$, while the "D" area includes the hysterons that are "down", since $I_t < b_i$. In order to show the input-output dynamics we can start from figure 1.8. If the Input raises to I_{t+1}, the U and D areas change as follows:

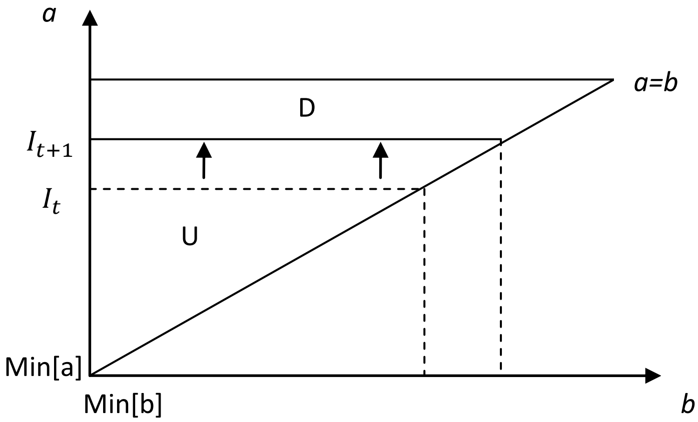

Figure 1.8: representation of a positive shock in the Mayergoiz's half-plane diagram. Positive shocks move on the vertical axis. Full lines identify the current state of the system; dotted lines identify the history of the system

After the shock, some hysterons switch to "up" and the U area becomes larger. Suppose now that the shock was only temporary, and that the Input reverts back to I_t:

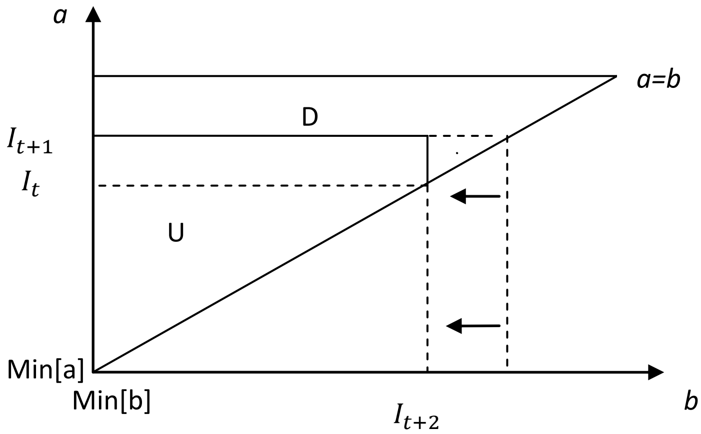

Figure 1.9: representation of a negative shock in the Mayergoiz's half-plane diagram.

The U area is now smaller, although bigger than at the very beginning. For instance, after the first shock some hysterons switched to "up" because $I_{t+1} > a_i$, and when the input reverted at the initial level, those hysterons did not revert back to down because still $I_{t+2} > b_i$. Hence, a temporary shock left permanent traces. This property of *genuine* hysteresis according to which temporary shocks can have permanent effects is called *remanence.* The difference with respect to unit-root persistence, which also implies that temporary shocks have permanent effects, is the non-linear *reversibility* of the process. Suppose a negative shock such that $I_{t+3} - I_t = -(I_{t+1} - I_t)$ followed by a positive shock such that $I_{t+4} = I_t$:

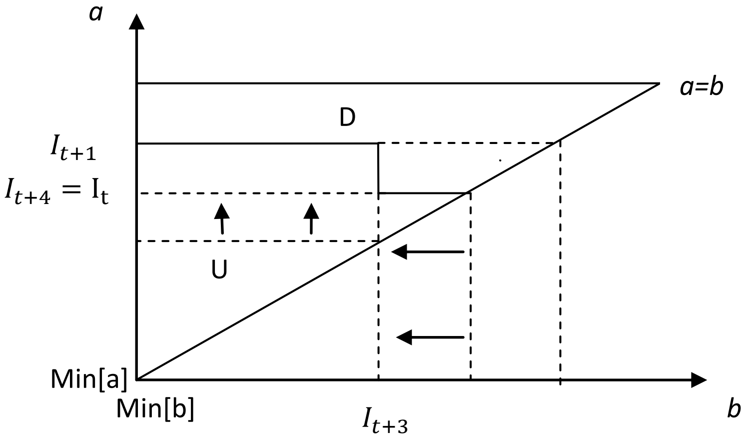

Figure 1.10: representation of a cumulatively neutral shock in the Mayergoiz's half-plane diagram.

The U area, which is the area below the full lines, is now bigger than the U area of figure 1.7, even though shocks were cumulatively neutral. In other words, all these shocks left a permanent trace that could not be erased just by reversing the process, hence just by applying a series of cumulatively neutral shocks. Notice that *remanence* does not imply irreversibility: the previous magnetic force can be potentially restored through a given sequence of shocks. Nevertheless, what distinguishes *remanence* from "full reversibility" is the way the system can restore the previous aggregate output: in unit root models, it is sufficient to trace back the same sequence of shocks; in *strong* hysteresis, it is not sufficient to have cumulatively neutral input shocks to have cumulatively neutral output shocks. However, some shocks can erase the memory of previous shocks. Suppose a negative shock such that $I_{t+5} = \min[b]$ and then a positive shock such that $I_{t+6} = I_t$:

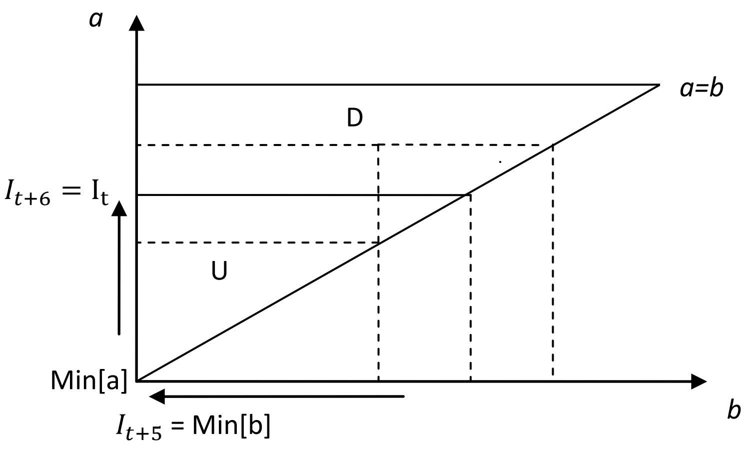

Figure 1.11: representation of a series of shock that erase the memory of the system

Figure 1.11 shows the *selective memory* property of *strong* hysteresis: the shock ΔI_{t+5} erases the memory of dominated shocks, namely ΔI_{t+1} to ΔI_{t+4}, that no longer determine the aggregate output level. Indeed, the cumulative effect generated by the whole series of shocks $[\Delta I_t, \Delta I_{t+1}, \Delta I_{t+2}, \Delta I_{t+3}, \Delta I_{t+4}]$ is equivalent to the cumulative effect generated by the shorter series $[\Delta I_t, \Delta I_{t+5}]$, the other shocks no longer provide information about the final state of the system; this would have not been the case in absence of I_{t+5} . Selective memory means that only *non-dominated* shocks remain in the memory bank of the system, as opposed to unit root processes that keep the whole series of past shocks in their memory bank. Furthermore, the shock ΔI_{t+6} is able to restore the initial state of the system, since *remanence* does not necessarily imply irreversibility, it only rules out linear reversibility through cumulatively neutral shocks. This point can be better understood by looking at Ewing's hysteresis loop in figure 1.12:

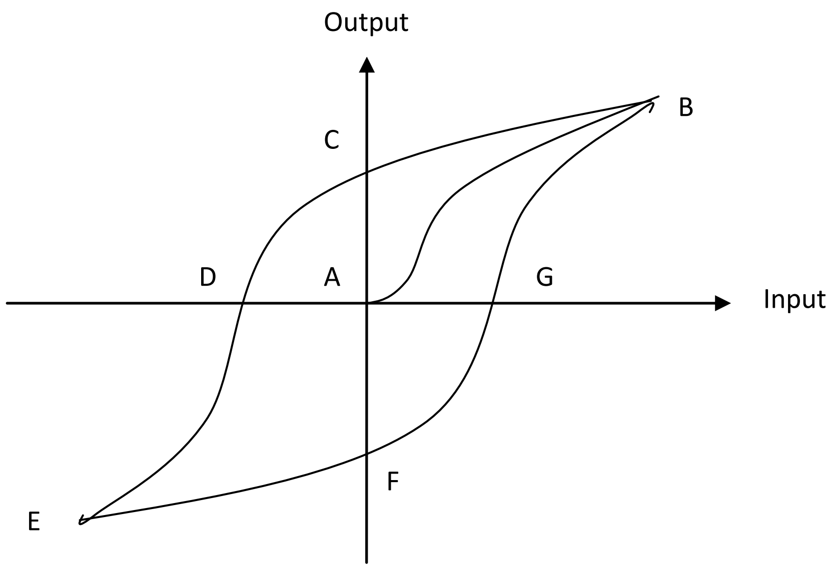

Figure 1.12: J.A. Ewing's hysteresis loop

It is possible to reach any point on the vertical axis in both directions, although a different input level is required. In other words, the points "A", "D" and "G" represent different input levels consistent with the same output: starting from A, if point B is reached, it is not possible to reach the same output of A just by getting back to the same input level, since at that input level the output will now be point C. In order to reach the initial output level it is necessary to move to point D, which implies, however, a different input. Therefore, although the system is not irreversible, it is not even linearly reversible. This is the main feature that distinguishes remanence from persistence: *remanence* implies that cumulatively neutral sequences of input shocks do not cancel out. The properties of *strong* hysteresis are similar to the properties of *weak* hysteresis, with some additional remarks:

1) History still matters, but only as regards non-dominated.
2) There is *remanence* for virtually any fluctuation of the input variable, according to the fact that firms are multiple and heterogeneous, and any cumulatively neutral shock will potentially affect some firms and be neutral with respect to others.
3) Remanence depends on the amplitude of the shocks, in particular as regards their quantitative effect: big shocks generally affect a larger share of micro-elements than small shocks. The effect, however, is still not proportional because of the heterogeneity in the threshold values.

The intuition behind the application of this model into economics is straightforward (Dixit, 1989; Cross et al, 1998, 2008; Zoega et al, 2002): in many economic decisions, the different possibilities involved can be simplified in a dualistic choice (investing/ not investing, hiring/not hiring). The final decision depends on the specific value that a given variable takes with respect to some critical thresholds. Suppose a firm that faces the decision whether to invest or not to invest in a new foreign market (Amable et al, 1994). This firm will invest if expected returns exceed expected costs. Since sunk costs cannot be recovered if the investment fails, the firm will require that expected returns be sufficiently high to fully compensate the risk of net losses. However, if the firms decided to invest and actual returns are lower than expected, it will make sure that the "exit" costs are lower than the costs of staying before disinvesting and abandoning the market. Formally, the firm's "entry" criterion will be the following (Setterfield, 1998):

$$\int_{t=n}^{N}(R_t - C_t)e^{-rt}\,dt > K \qquad (14)$$

where R denotes total revenues, C the variable costs, K the sunk costs of entry and r the rate of time preference. The "exit" criterion, on the other hand, will be:

$$\int_{t=n}^{N}(R_t - C_t)e^{-rt}\,dt < -K \qquad (15)$$

The reason is quite intuitive: when the firm has to decide whether to enter in a new market or not, its investment decision requires that the expected profits be higher than the value of the fallback position, which is equal to 0 by assumption. If the firm already invested, in order to exit the expected costs of staying (that do not include sunk costs, since they are paid *once for all*) need not be just higher than 0 but need to be higher than the costs of abandoning the market, which are equal to the "entry" costs (sunk costs).

Notice that, in order to have *weak* hysteresis, the existence of sunk costs, hence of two different switching values, is a necessary and sufficient condition. In order to have *strong* hysteresis two further assumptions are required: firms' multiplicity and heterogeneity. It can be easily argued that different sectors exhibit different sunk costs. Furthermore, firms can differ, within the same industry, in terms of managerial ability, financial constraints, productive techniques and future expectations. The influence of "animal spirits" and radical uncertainty on investment decisions is another important source of heterogeneity (Lang, 2009, pp. 141-142). To the extent that firms are heterogeneous, they will have different expectations concerning the future exchange rate and different critical thresholds. The non-ideal relay diagram describes the investment behaviour of each firm:

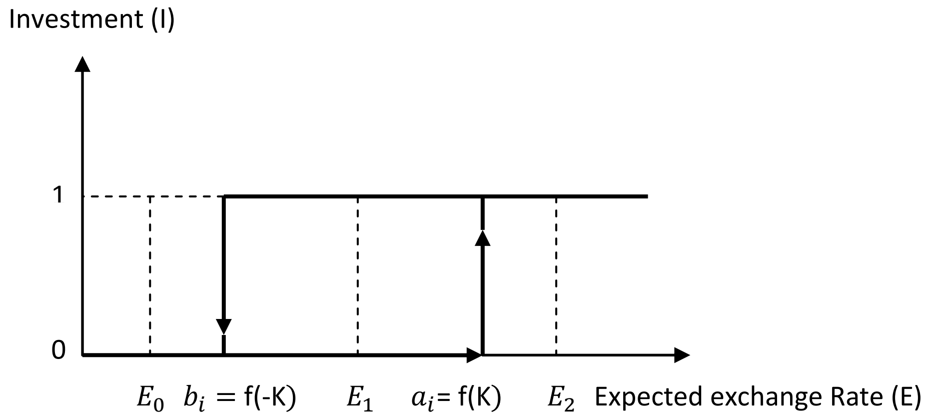

Figure 1.13: the non-ideal relay diagram with expected exchange rate as the input variable and investment as the output variable.

If expected profits are a function of the expected exchange rate, an inactive firm will decide to enter in the market (I=1) if the expected exchange rate is above the critical value $a_i = f(K)$. An incumbent firm, on the other hand, will decide to abandon the market (I=0) only if the expected exchange rate is below the critical value $b_i = f(-K)$, otherwise it would be better off to stay in even though its actual profits are lower than expected. Hence, the number of active firms in the foreign market will depend on expectations: if the expected exchange rate increases, all inactive firms with $E > a_i$ will enter in the market; if the expected exchange rate falls, only active firms with $E < b_i$ will exit from the market; all other firms, either active or inactive, will not change their strategy as long as $b_i < E < a_i$. The aggregation of firms' discontinuous adjustments of capital stock in response to real exchange rate fluctuations will generate *strong hysteresis* in aggregate capital stock fluctuations.

Empirical applications of this model are developed in Piscitelli et al (2000) on the Keynesian consumption multiplier, in Cross et al (1998) on the relationship between real exchange rate and unemployment and in De Peretti & Lang (2009) on Okun's Law.

1.3.4. Genuine hysteresis Vs unit root: non linearity, selective memory and remanence

There are strong theoretical and methodological differences between the two approaches to hysteresis that are dominant in economic literature, namely the unit/zero root approach and the genuine hysteresis approach.

First, the unit/zero root models are dynamic models of linear differential equations that identify hysteresis with the non-stationarity of the system. In particular, hysteresis is contingent to the existence of a zero eigenvalue in linear systems of differential equations or a unit root in difference equations. In the genuine hysteresis approach, on the other hand, hysteresis emerges from the aggregation of multiple and heterogeneous hysteresis operators that display a specific non-linear and discontinuous structure. However, it is not non-linearity *per se* that generates *remanence*, but the specific discontinuous relationship between output and input based on the existence of two distinct switching values. (Piscitelli et al, 2000) Hysteresis is interpreted as a discontinuous and non-linear process of adjustment of output in response to input shocks, in an economic environment characterized by multiplicity and heterogeneity. The same cannot be said for unit root models, where hysteresis emerges from a continuous and partial adjustment of output in an economic environment characterized by homogeneity.

Although the difference can appear to be purely methodological, the economic implications are often at odds. Unit root models of unemployment hysteresis implicitly assume that hysteresis is a very special case: since the unemployment rate is by definition bounded between 0 and 1, unemployment time series cannot be represented by random walks, which are stochastic processes characterized by a virtually infinite variance. Moreover, when the assumption of a unit root is tested against the alternative hypothesis of structural change, standard econometric tests fail to reject the null hypothesis of stationarity (Arestis & Mariscal, 1999; Papell et al, 2000). Therefore, if unemployment hysteresis means the existence of a unit root, the hysteresis hypothesis can be systematically rejected. To overcome such a limitation, the assumption of a unit root is often relaxed and the sum of the lagged variables is no longer constrained to be equal, but just close to 1. In this case, however, hysteresis would be associated with short run *persistence* or equilibrium multiplicity, consistently with a long term asymptotically stable equilibrium (Layard et al, 1991). Genuine hysteresis, on the contrary, implies the explicit reconsideration of asymptotic stability of the attractors: when discontinuous adjustment of heterogeneous agents takes place at the micro level, it is no longer possible to identify a unique and stable macroeconomic equilibrium, since transitory shocks might generate permanent effects, hence *remanence*. Consequently, hysteresis does not emerge as a special case but rather as a structural characteristic of environments characterized by heterogeneity and discontinuity. Furthermore, *strong* hysteresis is perfectly consistent with both stationary and non-stationary time-series (Amable et al, 2004), and it can explain a larger set of empirical observations with respect to strictly non-stationary models.

Second, random walks are stochastic processes that keep in their memory bank all past shocks, whatever their amplitude and duration, as it clearly appears from equation (3).The effect of input shocks on output is linear and proportional. Genuine hysteresis, on the other hand, is characterized by a selective and erasable memory (Cross, 1994). Moreover, although at a macro level some proportional effects can be found, these proportionality is only "quantitative", in the sense that a bigger shock is likely to imply the switch of a higher number of firms with respect to a small shock, but it is not linear and it depends on the sequence of past shocks. The property of selective memory has also important implications on the reversibility of the process. Since unit root processes keep the whole sequence of the previous shocks in the memory bank permanently, these processes display strict irreversibility, even though cumulatively neutral shocks perfectly cancel out in a fully reversible way (Amable et al, 1995). Genuine hysteresis, on the other hand, is characterized by *remanence,* which has different implications with respect to either *persistence* or unit root instability. Although *remanence* implies that "transitory shocks have permanent effects", these permanent effects do not cancel out just by reverting the process but they are not even irreversible: "many subsequent time paths are possible for different sequences of shocks, including a return to the original steady-state unemployment level. (…) There are costs involved in the restoration of the *status quo ante*, but not irreversibility" (Cross, 1993B, p. 307). For these reasons, it would be more appropriate to speak about *persistence,* rather than hysteresis, when dealing with unit/root models (Amable et al, 1994).

Asymptotic stability, unit root instability and *remanence* represent radically different macro-dynamic frameworks that are not necessarily compatible each other. In particular, while the unit- and zero- root approaches are consistent with long run asymptotic stability (hysteresis being confined to the existence, in the short to medium run, of a unit- or zero-root), failing to reject the NRH, *genuine* hysteresis is definitely incompatible with a long run *natural* rate of unemployment. *Genuine* hysteresis is the opposite of the NRU, its falsifying hypothesis (Lang, 2009, p. 109).

1.3.5. Policy implications and concluding remarks

According to the neoclassical theory, the long run is *naturally* characterized by a balanced growth path that is exogenous with respect to effective demand. Monetary policy can at most stabilize the cycle around its long run trend but it cannot modify the trend. Even though introducing the possibility that temporary shocks might have permanent effects implies, to a smaller or larger extent, the reconsideration of the NRH, the degree of rejection of the mainstream asymptotically stable framework can be consistently different. According to Ball & Mankiw (2002) and Ball (2009) *hysteresis* does not invalidate the classical NRU framework but rather integrates it: to the extent that the NRU is made endogenous, the model still holds and gains in terms of empirical consistency:

"Allowing for hysteresis can greatly change our explanations for unemployment movements and our prescriptions for monetary policy. However, I don't view hysteresis as a radical departure from mainstream economic theory. It is not a rejection of Friedman's model, but a generalization of it. We expand the set of factors that cause the U* term (..) to change over time: these factors include movements in actual unemployment as well as supply-side variables." (Ball, 2009, p. 8)

To state that the NRH can be consistent with the *hysteresis hypothesis*, however, is tantamount to confining hysteresis to a short run departure from the long run asymptotic stability assumption. In other words, to the extent that hysteresis represents a special case of an otherwise asymptotically stable long run, the dichotomy short-run/long-run still holds: in the short run the economy might exhibit hysteresis, but in the long run the NRH cannot be rejected. If, however, the *hysteresis hypothesis* is supposed to hold in a long run horizon, the NRH will not hold any longer. Indeed, to the extent that the long run NRU/NAIRU is a weak attractor or even an *attractee*, most of its operational and conceptual power would be definitely lost, and by losing all its predictive power the NRU/NAIRU would be no longer an interesting reference concept to analyse macroeconomic dynamics (Sawyer, 1997; Stanley, 2002; Palumbo, 2008). Questioning the stability of the equilibrium implies therefore questioning the validity of the concept of equilibrium as an analytical tool. In Miroshima's words:

"If economists successfully devise a correct general equilibrium model, even if it can be proved to possess an equilibrium solution, should it lack the institutional backing to realize an equilibrium solution, than that equilibrium solution will amount to no more than a utopian state of affairs, which bears no relation whatsoever to the real economy" (Miroshima, "the good and bad uses of mathematics", quoted in Kirman, 1992)

Since the “natural rate hypothesis” requires a relatively stable equilibrium and implies monetary policy neutrality, hysteresis must lead to a rejection of the NRH as long as it implies a large equilibrium instability and monetary policy non neutrality.

According to Ball et al (2011), for instance, monetary policy explains a large share of unemployment, especially in the aftermath of recessions. Starting from the empirical evidence that unemployment raised and stabilized upwards in some countries, while it returned back to the initial level in others, they find a positive correlation between real interest rate and unemployment: strong and sudden reductions of the real interest rate were associated with falling rates of unemployment; sluggish real interest rates with higher and stable unemployment rates. Hence, full employment stability would require a discretionary and asymmetric monetary policy: if inflation decelerates, central banks should suddenly lower the interest rates in order to prevent unemployment to become structural. When on the other hand inflation increases, the interest rate should be kept relatively low in order to allow a structural fall in the NAIRU before stabilizing inflation again. The opposite behaviour, consisting of increasing the interest rate in response to small increases of inflation and not lowering the interest rate when inflation decelerate, would rather hamper recoveries and structuralize cyclical unemployment. According to Schettkat & Sun (2009), for instance, German unemployment persistence in the last four decades can be attributed to an asymmetric monetary policy of the Bundesbank: when the economy was supposedly overheating, the Bundesbank immediately raised the interest rate in order to prevent an increase of inflation. When, however, the economy was slowing down it kept real interest rates relatively higher by raising the NAIRU. The authors blame the excessive emphasis on price stability and, in particular, the systematic incapacity to correctly estimate the “output gap”. If potential output is assumed to be always, *on average*, equal to actual output, and consequently potential output is estimated as the weighted mean (or as a smoothed series) of the business cycle, the risk of under- or over-estimating potential output sharply increases, since any recession or any boom will be soon considered, *on average*, as structural. Therefore, underestimating potential output leads to restrictive monetary policies to the extent that the lower output is considered to be structurally lower.

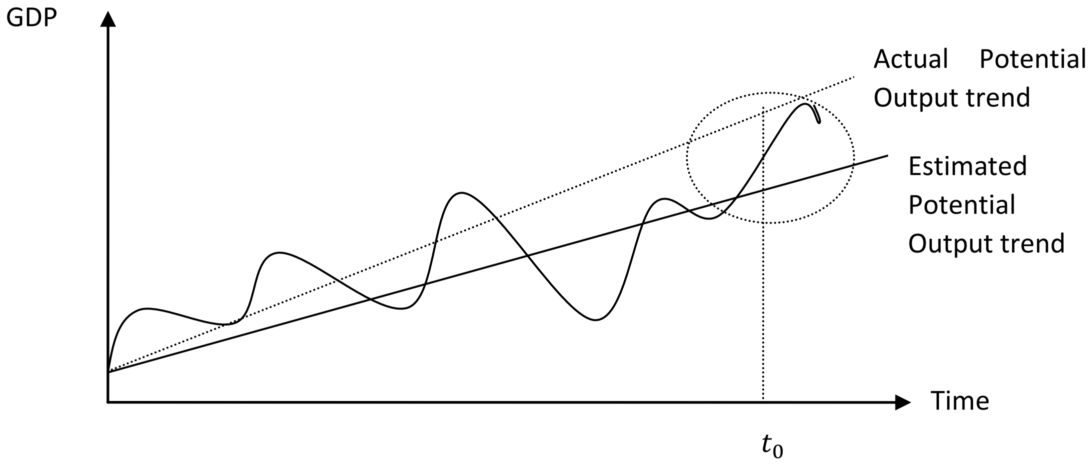

Figure 1.14: Actual Vs potential output. The consequences of estimation biases.

Suppose the central bank is only interested in price stability and sets the interest rate according to the estimated output gap, which is the difference between actual output and (estimated) potential output: when the output gap is positive because actual output lies above potential output, unemployment lies below the NAIRU and the central bank will increase the interest rate in order to prevent an increase of inflation; when, on the other hand, the output gap is negative because actual output lies below potential output, unemployment lies above the NAIRU and the central bank reduces the interest rate in order to prevent a deceleration of inflation. If the central bank assumes that actual output naturally gravitates around potential output and at time t_0 estimates potential output as the average trend of real output, it might interpret a negative output gap as positive output gap and increase the interest rate in order to stabilize the economy on the improperly estimated long run trend. The consequence is a pro-cyclical monetary policy that turns cyclical unemployment into structural.

Therefore, introducing hysteresis in unemployment implies reconsidering the role of countercyclical demand policies, which do not merely stabilize demand around an independent supply but they rather determine the long run trajectory of the economy. Moreover, if hysteresis is a structural property of economies characterized by heterogeneous and discontinuous adjustment behaviours - rather than a special case of unit root persistence - the whole validity of the mainstream framework, as well as the policy prescriptions based on this framework, are called into question. Chapter 2 will show, for instance, that introducing genuine hysteresis in a “new consensus” framework radically changes the policy implications of the model. Namely, demand shocks might imply a permanent loss of productive capacity according to the amplitude of the shock and the reaction of the central bank. Furthermore, monetary and fiscal policies become a fundamental tool to set the economy around a range of endogenous long run steady states instead of merely stabilizing demand around a unique (or a predictable multiplicity of) exogenous long run trend. Hence, *genuine* hysteresis implies a full reconsideration of the NRH and its policy neutrality implications, it definitely rules out any "Natural Rate Hypothesis".

2. Discontinuous entry and exit decisions. Long run non-neutrality of demand policies

2.1. Introduction

Section 2 of chapter 1 concentrated on recent developments in macroeconomic theory as regards how path-dependency and hysteresis have been introduced in standard macroeconomic analysis based on equilibria that are allegedly *natural*. We can distinguish three different approaches to make the NRU/NAIRU model consistent with empirical evidence of raising unemployment in most European countries, especially in the 1980's. A first approach refers to the assumption of a high persistence in the process of disequilibrium adjustment that might generate a multiplicity of short- to medium- run NAIRUs because of cost-push shocks and developed rigidities in the labour market triggered by, for example, welfare institutions and employment regulation (Layard et al, 1991; Nickell et al, 1996; Gordon, 1997, 1998; Richardson et al, 2000; Ball & Mankiw, 2002). By defining the short-run NAIRU as the level of unemployment consistent with stable inflation *in the current period*, the unemployment rate might temporarily fluctuate around a higher or lower equilibrium although it must, sooner or later, revert to the unique, long run NAIRU (Cross & Lang, 2011). A second approach focused on the possibility of supply-side structural changes characterizing the NAIRU as a time-varying equilibrium (Gordon, 1997, 1998; Richardson et al, 2000; Ball & Mankiw, 2002). In this framework, the NAIRU is still an asymptotically stable equilibrium that can vary because of supply side shocks, namely technological development, openness to trade and financial liberalization among others. The endogenous relationship between demand and supply is, however, still rejected (or at least not discussed). While these two approaches are consistent with the standard theory of a long run stable NAIRU, the third one explains raising unemployment by assuming a radical violation of the NRH. In particular, it is assumed that long-term unemployment deteriorates the human capital of workers, who lose the capability to exert a downward pressure on real wages. When this happens, the NAIRU completely loses its attractive force and fully adjusts to real unemployment variations: rather than observing real unemployment adjusting to the equilibrium we would observe the equilibrium adjusting to current unemployment. The unemployment rate dynamics would consequently be suitable represented by a random walk. The *hysteresis hypothesis* has largely influenced the macroeconomic debate. To the extent that unemployment exhibits hysteresis, the fundamental neoclassical conclusion of the vertical Phillips curve and the consequent money neutrality is rejected; consequently, forecasts based on the short-run unemployment-inflation trade-off lose their predictive power.

The new mainstream macroeconomic paradigm that has been rapidly developing in the last two decades (Clarida et al, 1999, 2000; Allsopp & Vines, 2000; Taylor, 2000; Mc Callum & Nelson, 2000; McCallum, 2001; Woodford, 2001, 2003), often defined as the "new neoclassical synthesis" or "new consensus in monetary macroeconomics" (NCM) (Fontana & Palacio-Vera, 2005; Lavoie, 2006), seems to have only partially been affected by this debate. In the "new consensus" view, the analysis of business cycles does not focus any longer on the labour market even though it is mostly based on the same theoretical assumptions than the NRU/NAIRU models. In particular, the dichotomy between actual and natural unemployment has been replaced by the dichotomy between actual and natural output (Clarida et al, 1999). Based on this assumption, the short-run unemployment-inflation trade-off has been also replaced by a short-run output-inflation trade-off, and the standard expectations augmented Phillips curve substituted by a similar price rule in which the output gap, which is the difference between actual and natural output, replaces the unemployment gap, which is the difference between actual and natural unemployment or, in alternative words, the difference between the actual rate of capacity utilization and the non accelerating inflation rate of capacity utilization (NAIRCU) (Gordon, 1998; Nahuis, 2003).

The real novelty of this framework seems to be the relevant role played by monetary policy in stabilizing short run fluctuations. In the NAIRU model, for instance, the stability of the equilibrium was assumed *a priori* relying on a simple real balance effect (see section 1.1.5.). Nevertheless, by assuming the existence of rigidities in price setting that prevent actual output to adjust to natural (or potential) output, the equilibrium stability is no longer guaranteed, and the interest rate becomes the relevant fine-tuning variable to stabilize output fluctuations around potential output . The role of the central bank in these models is to target the Wicksell's *natural* rate of interest, which is the rate of interest that guarantees the adjustment of real to natural output, by setting a higher-than-natural rate when inflation accelerates and a lower-than-natural rate when inflation decelerates. By following a simple inflation target, monetary authorities could thus stabilize positive and negative fluctuations by setting the proper interest rate according to the signal received by the market, respectively acceleration or deceleration of inflation.

The strength of this framework is twofold. On one hand it allows to overcome the problem of unemployment hysteresis by simply ignoring the labour market, in order to concentrate on the capacity utilization-inflation trade-off and the role of monetary policy in ensuring at the same time inflation stability and full capacity utilization.

From this point of view, the NCM represents a step forward with respect to the NRU and NAIRU frameworks. For instance, the assumption of price rigidities is consistent with the *disequilibrium persistence* and *multiplicity of equilibria* approach to hysteresis. Moreover, to the extent that supply shocks can affect the output-inflation trade-off, persistent cost-push shocks might generate a multiplicity of short run output equilibria that are different from the long run natural output. The stabilizing role that monetary policy plays in these models represents at the same time the recognition that the long run equilibrium is unstable and that monetary policies are fundamental to stabilize the economy (Ball et al, 2011) and, on the other hand, an *immunization* of the model with respect to hysteresis by assuming that monetary policy alone is able to stabilize the economy, provided that the central bank succeeds in correctly estimating the *natural* rate of interest and targeting a fixed and steady rate of inflation. Therefore, the "new consensus" framework seems to provide an answer to the *hysteresis hypothesis* by introducing monetary policy as a stabilizing device, and suggests interpreting persistent fluctuations as either caused by an inefficient central bank that chooses the wrong monetary rule (Clarida et al, 2000) or by exogenous structural changes, consistently with the time-varying NAIRU approach. For instance, natural/potential output in these models seems to be strictly independent from real output. Clarida et al (1999) and Woodford (2001), by modelling potential output as a stationary process independent on output gap, clearly separate growth and business cycles. In McCallum & Nelson (2000), potential output is a function of a technology shock term and import prices, independently on output gap. Taylor (2000) is vaguer on this point. On one hand he argues that potential output evolves according to a classical Solow model augmented with endogenous technology, suggesting a form of endogeneity in potential output evolution. Nevertheless, it clearly distinguishes economic growth and economic fluctuations in two distinct chapters: while growth depends on endogenous technology growth, economic fluctuations are explained by price rigidities and monetary policy reactions, and there are no explicit links between business cycles and technological growth. Hence, even though growth is assumed to be endogenous to demand fluctuations, it is actually treated in the model as if it was exogenous.

Latest contributions to the “new consensus” framework tried to formally reconcile the standard three equations model with the hysteresis hypothesis (Kapadia, 2005; Fontana & Palacio-Vera, 2005; Lavoie, 2006; Kienzler & Schmid, 2014) by adding a fourth equation to the model that defines an endogenous process (equivalent to the unit root process) of potential output adjustment to real output variations. In particular, potential output (potential output growth) is modeled as a linear function of past potential output (past potential output growth) and past real output (past real output growth), according to the following linear characterization (Hargreaves-Heap, 1980):

$$Y_t^n = (1 - \Phi) * Y_{t-1}^n + \Phi * Y_{t-1} + \varepsilon_t \qquad (1)$$

With $0 < \Phi < 1$. Note that this characterization of *hysteresis* amounts to a *quasi-unit-root* model: by setting $\Phi = 1$ the dynamic process of potential output adjustment becomes a unit root process.

When equation (1) is introduced into the model, the system exhibits a zero root, and the policy implications suddenly change. Supply-side negative shocks generate policy-induced recessions (Fontana & Palacio-Vera, 2005; Lavoie, 2006): to the extent that the central bank targets a fixed rate of inflation, a cost-push shock implies a monetary restrictive policy that affects output and thereby potential output, the new equilibrium being characterized by steady inflation but lower output. The same applies for supply-side shocks to potential output (Kapadia, 2005; Lavoie, 2006): a transitory but persistent negative shock to potential output (i.e. a technological shock) would raise the output gap and generate inflationary pressures, that the central bank puts out by increasing the interest rate and adjusting output downwards. The new equilibrium will be characterized again by steady inflation and lower output.

The same does not apply, however, in case of demand shocks (Lavoie, 2006) or monetary policy shocks (Kienzler & Schmid, 2014): a temporary shock that raises or lowers current output respectively above or below potential output can be perfectly neutralized by a standard monetary policy rule without any consequence of potential output. In this case, for instance, the temporary shock would initially imply a deviation of output from potential output and, through equation (1), a dynamic movement of potential output itself. However, the reaction by the monetary authority would imply an equal force of opposite sign that would eventually imply the same dynamic process but in the opposite direction. As a consequence, the economy would only temporary deviate from the initial equilibrium but then return back to the original level of potential output. In other words, the equilibrium is eventually characterized by global stability[4]. Introducing a unit/zero root in "new consensus" models highlights therefore the importance of distinguishing between demand and supply side shocks when a central bank targets a fixed rate of inflation. For instance, in case of demand shocks, targeting inflation stability turns out to be a successful policy. In case of supply side shocks, however, the emphasis on price stability would create policy induced recessions that persist in the long run, unless a positive supply side shock of same amplitude brings the economy back to the original equilibrium, consistently with the "full reversibility" property of unit root models (see section 1.2.3.3.).

Chapter 2 develops a standard "new consensus" model with "genuine" hysteresis. Instead of modelling potential output adjustments as a unit root process, it is assumed that a variety of heterogeneous firms with different sunk costs, different expectations and different market demand elasticity adjust discontinuously capital stock to expected profits variations. Each firm can decide whether to enter/stay in the market and produce with 1 unit of capital, or exit/not to enter in the market and have 0 units of capital. Since the investment decision is made under fundamental uncertainty (Keynes, 1921; Knigth, 1921) and implies sunk costs (Dixit, 1989), potential new firms enter in the market only if expected profits fully compensate sunk costs; incumbent firms exit from the market if expected losses are higher than sunk costs. If expected profits or losses are respectively lower or higher than sunk costs, firms do not invest nor scrap their capital stock and just wait for more information (see section 1.3.3.). By introducing this non-linear and discontinuous adjustment in firms investment decisions, economic and policy conclusions radically change. In "new consensus monetary" models with genuine hysteresis, for instance, the distinction between supply and demand shocks becomes less relevant to policy decisions, since both types of shocks would imply a shift in the final equilibrium. This is one of the main differences with respect to unit/zero root models of hysteresis: in "new consensus" models with zero root persistence the effects of transitory demand shocks cancel out in the long run equilibrium; in the "new consensus" model with genuine hysteresis, demand shocks leave a permanent scarce in long

[4] Palacio-Vera (2009) shows that by introducing a non-linearity in the price equation, temporary demand shocks may have permanent effects, despite potential output dynamics are modeled via equation (1). Nevertheless, this chapter considers NCM models with a linear accelerationnist Phillips curve and a hysteretic potential output equation.

run output. In this framework, counter-cyclical monetary policies are no longer able to target fixed output equilibria even though shocks are merely transitory and cumulatively neutral, since equilibrium is fully endogenous and hysteretic. Discretionary monetary and fiscal policies become crucial not only to smooth aggregate fluctuations but also to determine the long run equilibrium of the economy, which is fully endogenous.

2.2. A "new consensus" monetary model with genuine hysteresis

2.2.1. The standard "new consensus" model

Consider a simplified standard New-Consensus model characterized by the three well-known fundamental equations (Allsopp & Vines, 2000; Taylor, 2000; Lavoie, 2006):

$$\begin{cases} g = g_0 - \beta r + \varepsilon_1 & (2) \\ \dot{\pi} = \eta g + \varepsilon_2 & (3) \\ r = r_n + \zeta(\pi - \pi_T) + \gamma g + \varepsilon_3 & (4) \\ r_n = \frac{g_0}{\beta} & (5) \end{cases}$$

Equation (2) represents the New-Keynesian IS curve, where g_0 represents a structural disturbance that captures the autonomous demand side components, including government expenditure, r represents the real interest rate, β a fixed parameter, g represents the output gap, which is the difference between actual and potential output, and ε_1 a white noise stochastic shock responding to the following dynamic $\varepsilon_{1,t} = \sigma\varepsilon_{1,t-1} + \hat{\varepsilon}_1$ with $E(\hat{\varepsilon}_1) = 0$[5]. Potential output is defined in this model as the level of output consistent with a steady state rate of inflation, in other words potential output represents the inflation barrier: when the output gap is positive inflation accelerates, when the output gap is negative inflation decelerates. This characterization of the output gap is explicit in equation (3), where $\dot{\pi}$ represents the rate of growth of inflation, η a fixed parameter and ε_2 a white noise stochastic shock[6]. Equation (4) represents the central bank's monetary policy rule, which is supposed to replace the neoclassical theory of loanable funds, represented by the old LM curve, with a theory of endogenous money in which the central bank cannot directly control the stock of

[5] ε_1 might represent either a stochastic demand shock or a fiscal policy shock. In the remainder of the chapter it will be treated as a fiscal policy shock.

[6] This characterization of the accelerationist Phillips curve implies simple backward looking expectations. For an overview of different inflation rules with forward-looking expectations refer to Kapadia (2005)

money but can fix an interest rate according to a "reaction function" (Lavoie, 2006); r_n represents the Wicksellian "natural" real rate of interest, π_T the inflation rate targeted by the central bank, ζ and γ represent fixed parameters and ε_3 a white noise stochastic shock [7].

2.2.2. Potential output and "genuine" hysteresis

Implicit to the standard new-consensus model is the idea that potential output is substantially independent on aggregate demand and real output fluctuations (Fontana & Palacio Vera, 2002; Lavoie, 2006). In other words, there is a "hidden equation" (Lavoie, 2006) that tells:

$$Y^p = \bar{Y}^p \qquad (6)$$

This equation does not necessarily imply that potential output is constant. Indeed, potential output can be a time-varying variable as long as supply side shocks change the structural conditions of the equilibrium (Gordon, 1998; Nahuis, 2003). Equation (6) implies that although potential output is not time-independent, it is fundamentally demand-independent since it is not affected by real output fluctuations, and can be treated as fundamentally unique and globally stable provided that supply side shocks are ruled out by assumption or they are assumed to be exogenous[8]. Consequently, temporary demand shocks cannot have long lasting effects on the equilibrium conditions: in the long run real output converges towards potential output because of aggregate supply stability and because of monetary policy based mechanisms of disequilibrium adjustment (Clarida et al, 1999; 2000; Taylor, 2000; Allsopp & Vines, 2000).

In particular, demand adjusts to supply through equations (3) and (4). According to equation (3) a positive (negative) output gap implies an increasing (decreasing) inflation. To the extent that the central bank is able to correctly estimate the "natural" rate of interest, according to equation (4) the positive (negative) gap between actual inflation and targeted

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[7] The values of the parameters used during the simulations are provided in Appendix 1

[8] It can be argued that standard New Consensus models do no aim at explaining growth but rather business cycle fluctuations, and therefore they assume potential output stability only for simplicity. According to Taylor (2000), for instance, potential output is obtained through a Solow model augmented with endogenous technological change. However, the decision to clearly distinguish the long run growth behavior from a short run cyclical behavior must necessarily rely on the hypothesis of substantial independence of the growth path from business cycle fluctuations. Clarida et al (2000), for instance, clearly specify potential output as a AR(1) process: potential output fluctuations are therefore explained through stationary and stochastic exogenous shocks, independently from business cycle fluctuations. In other words, even though potential output is assumed to be *theoretically* endogenous, it is actually treated as if it were exogenous.

inflation will trigger a raise (fall) of the interest rate up to the "natural" rate, which is the rate of interest that equalizes aggregate investments and aggregate savings, hence real output and potential output. Consequently, the economy will stabilize again along with a steady and targeted inflation rate, a "natural" interest rate and a zero output gap. In this model, the assumption of potential output stability is relaxed. In particular, firms' potential output is defined as the level of output consistent with a "normal" utilization of the productive capacity installed, where by "normal" rate of capacity utilization it is generally meant the rate of capacity utilization that implies the minimum cost for firms (Kurz, 1986; Nikiforos, 2013). It is widely held, however, that firms tend to keep idle capacity in order to be able to face unexpected peaks of demand and not losing market shares with respect to actual and potential competitors. In other words, idle capacity can be on one hand a deterrent for new entrants and on the other hand a competitive strategy (Lavoie, 1996; Palumbo & Trezzini, 2003). Therefore, the "desired" rate of capacity utilization, which can be considered as the optimum target for firms, is not necessarily cost minimizing and it does not necessarily represent an "inflation barrier". Since potential output is generally meant to be the maximum level of output achievable without triggering pressures on inflation, the "desired" rate of capacity utilization cannot be considered as a measure of potential output, while the "normal" rate of capacity utilization can. For the sake of simplicity, we assume that normal and desired rates coincide, and that the "normal" rate of capacity utilization is stable because of the stabilizing role of prices: firms reduce (increase) prices when utilization is below (above) the "normal" rate and expand (reduce) their market demand until the "normal" rate of capacity utilization is reached, consistently with equation (3). We also assume for productive capacity a Leontief production function, with scarce capital and constant full-capacity output to capital ratio equal to 1 (A = 1) for simplicity. In economic terms, this hypothesis implies that production is a function of capital stock only, consistently with the empirical findings of Rowthorn (1999):

$$\begin{cases} {y_i}^{pc} = \min[AK_i; BL_i] = AK_i = K_i \\ {y_i}^{p} = \bar{u}_n {y_i}^{pc} = \bar{u}_n K_i \end{cases} \tag{7}$$

Consistently with the standard models of "genuine" hysteresis (Piscitelli et al, 2000; De Peretti & Lang, 2009; Cross et al, 2012) there is full capital indivisibility, consequently firms' investment decisions come down to a binary choice: either entering in the market with a stock of capital equal to K^a or exit from the market by scrapping their capital stock. Since investment decisions are taken in a radically uncertain environment (Keynes, 1921) and they imply sunk costs that cannot be recovered after the investment is made (Dixit, 1989), they display a non-linear and discontinuous dynamic. In particular, new entrants wait for aggregate demand to be higher than a certain investment threshold, say a, in order to invest and install a capital stock equal to K^a. Incumbent firms, on the other hand, wait for aggregate expected demand to be lower than a disinvestment threshold, say b, before scrapping the capital stock and exit from the market. By using the output gap relative to potential output as a proxy for aggregate demand, it is possible to represent investment decisions as in figure 2.1:

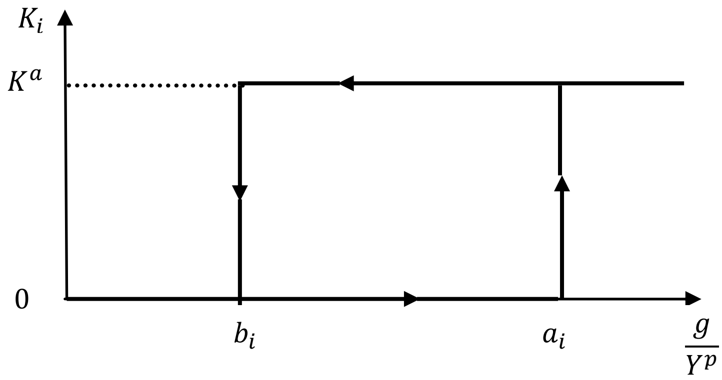


Figure 2.1: The non-ideal relay

If the output gap is above a, a new firm will found convenient to install a productive capacity equal to K^a and entering in the market, while an incumbent firm will just decide to stay in the market. If the output gap is below b, an incumbent firm will find convenient to scrap productive capacity and exit from the market, while a new potential entrant will just wait for better times before entering in the market and investing. If however the output gap is in between a and b, the incumbent firm will not find convenient to exit and a new potential entrant will not find convenient to enter in the market. In other words, in between a and b there is a “zone of inaction” that leads both potential new entrants and incumbent firms not to change their strategy and wait for new information before taking a decision that implies unrecoverable costs. The decision of a firm to enter or exit from the market is a path-dependent decision:

$$K_i = \begin{cases} K^a & if\ \frac{Y}{Y^p} > a_i \\ K^a & if\ \frac{Y}{Y^p} > b_i \quad and\ K_{i,t-1} = K^a \\ 0 & if\ \frac{Y}{Y^p} < a_i \quad and\ K_{i,t-1} = 0 \\ 0 & if\ \frac{Y}{Y^p} < b_i \end{cases} \tag{8}$$

The selective memory property of “genuine” hysteresis arises from the existence of this “zone of inaction” in which incumbent firms do not exit and potential new entrants do not enter. Starting from this zone, a temporary shock that is able to induce incumbent firms to exit or potential new firms to enter will leave permanent traces on these firms: the incumbent firms that decided to exit because of a temporary negative shock will not enter again when the shock is over, and potential new entrants that decided to enter because of a temporary positive shock will not decide to quit the market when the shock is over. A temporary shock, either positive or negative, will leave permanent traces only if it is able to induce some potential new entrants to permanently enter in the market or incumbent firms to permanently exit, while it will leave no traces if it is not able to induce any firm to quit their zone of inaction.

For the sake of simplicity, both *a* and *b* are exogenous and constant over time, a common assumption in standard models of genuine hysteresis (Piscitelli et al, 2000; Amable et al, 2004; De Peretti & Lang, 2009). Consistently with standard models of genuine hysteresis, firms are heterogeneous with respect to these switching values. It is reasonable for instance to suppose that different economic sectors have different sunk costs according to the specific characteristics of the markets. Furthermore, within the same sector and the same market, firms can have a different demand and different expectations concerning how demand will evolve in the future, hence a different propensity to take risk and invest. For instance, firms observe the same aggregate demand shock (aggregate output gap) and on this basis they form expectations concerning how their own market demand will evolve in next periods. For example, some industries might not benefit at all from a little and positive aggregate demand shock to the extent that the higher demand would be addressed to other industries; therefore, they will need a bigger positive aggregate demand shock in order to have a little positive increase in own market demand. The same applies for small negative aggregate demand shocks: some industries will lose a consistent amount of demand as a consequence of the downturn while some others will be only partially affected. The effect on individual output for each firm depends on the different sensitivity to aggregate demand shocks, and it is different for each firm as long as each firm (or industry) has a specific market demand elasticity to aggregate demand shocks. Animal spirits will also affect the relative position of the switching values and the way firms respond to aggregate demand shocks. To the extent that a firm is particularly optimistic, a small positive increase in aggregate demand will be sufficient to enter in the market since it will be interpreted as a sign of a long lasting growth period. At the same time, optimistic firms will also interpret a downturn as merely temporary and will not consequently scrap productive capacity. A pessimistic firm, on the other hand, will more rapidly disinvest when demand falls and will wait for a higher demand before entering in the market. Hence, an optimistic firm will have a relatively lower a and a relatively lower b with respect to a pessimistic firm, since positive demand shocks will be interpreted as a sign of a boom and negative demand shocks as temporary downturns.

The threshold values will be different for each firm if there is a unique input but different elasticities of market demand with respect to aggregate demand variations, different expectations concerning aggregate demand evolution and different sunk costs. Because of heterogeneous sunk costs, heterogeneous expectations and heterogeneous elasticities of individual demand with respect to aggregate demand variations, aggregate potential output cannot be represented as a representative firm's behavioral equation but rather as the aggregation of heterogeneous firms taking independent decisions. Differently from the standard "new consensus" model that assumes a unique representative firm, aggregate potential output is the sum of heterogeneous firms' potential output:

$$Y^p = \sum_{i=1}^{n} {y^p}_i \tag{9}$$

Next section shows the simulations of a standard "new consensus" model in which firms' decision to increase or to scrap productive capacity depend on equation (8), consistently with the "genuine" hysteresis paradigm. Differently from standard models of "genuine" hysteresis, however, the input is no longer exogenous since it depends on equations (2) to (5). The aim of the simulations is to compare the emerging results in terms of monetary and fiscal policy effectiveness with standard NC models (Clarida et al, 2000; McCallum, 2001, Woodford, 2001, 2003) and NC models augmented with linear hysteresis (Kapadia, 2005; Fontana & Palacio-Vera, 2005; Lavoie, 2006; Kienzler & Schmid, 2014; Fontana & Passarella, 2014).

2.3. Productive capacity adjustments: structural change Vs temporary persistence

Simulations are performed in the multi-agent simulation environment $Netlogo^{©}$. There are 100000 firms having the same full-capacity output to capital ratio (A = 1) and the same rate of "normal" utilization, $u_{n,i} = \bar{u}_n$, but different switching values according to a uniform distribution[9]. We simulate different monetary policy scenarios consisting of different weights put on output stability in the central bank's reaction function, using the same random-seed in all scenarios in order to isolate the monetary policy effect, and fixed monetary policy coefficients but different random seeds in order to isolate the effect of the initial position. Eventually, results are compared with those emerging from a standard New-Consensus model with constant potential output and a linear hysteresis-augmented "new consensus" model (Lavoie, 2006; Fontana & Passarella, 2014).

2.3.1. Permanent effects of temporary shocks and long run non neutrality of economic policies

Figure 2.2 shows the impact of a temporary negative shock to $\hat{\varepsilon}_1$ with different random-seeds.

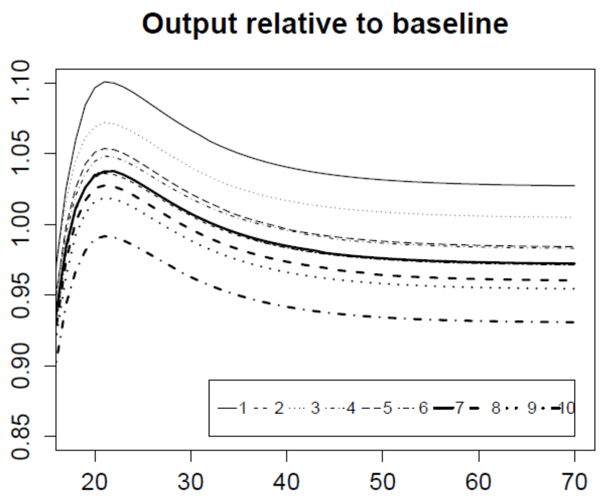


Figure 2.2: Output dynamics with different random seeds

The hysteresis effect of a temporary shock is substantially different across simulations depending on the starting point: different random-seeds imply different starting points, hence different share of firms starting on their "inaction zone" and changing their strategy in the wake of the shock. The same shock, whatever its amplitude, might have different effects on final output according to the sequence of past shocks. Furthermore, the final equilibrium is fully undetermined: instead of stabilizing along multiple predictable steady states, the system can stabilize in a continuum of possible equilibria that cannot be predicted unless the initial

[9] The specific random distribution does not affect the results and properties of the model (Piscitelli et al, 2000)

position of each firm that reacts to the shock is common knowledge. In most cases the negative shock is sufficiently high to prevent a full recovery and the economy permanently stabilize downwards. The reason is that following the negative shock some firms exit from the market and consequently depreciate the overall productive capacity. Since both the output gap and inflation fall, the central bank lowers the interest rate in order to boost demand and stabilize the output around its (lower) potential. The final outcome is a permanently lower output along with steady inflation and "normal" utilization of (a lower) capacity. These scenarios are consistent with the capital shortage explanation of unemployment hysteresis (Van de Klundert & Van Schaik, 1990; Arestis et al, 2007 and references therein): the existence of sunk costs and the consequent discontinuity of investment decisions might explain why, despite the recovery, productive capacity does not revert to the initial level, a critical remark that has often been raised to capital shortage theories blamed for not being able to provide a theoretical explanation of hysteresis (Blanchard & Summers, 1986; Lang, 2009). Figure 4, however, also shows some apparently counterintuitive results. In some cases, for instance, the economy stabilizes upwards along with a higher output despite the negative shock. The reason is that the negative shock does not generate an important wave of exit; therefore, when the central bank lowers the interest rate, the recovery is sufficiently strong to induce new firms to enter in the market and increase the overall productive capacity. As a result, when the economy stabilizes along with steady inflation and "normal" capacity utilization, the overall productive capacity is permanently higher.

The final outcome depends on both the amplitude of the shock and the monetary policy reaction of the central bank, which affects the capability of the economy to absorb the initial shock and prevent large waves of firms' exit. Figure 2.3 shows the impact of the same shock, starting from the same starting point (i.e. same random seed)[10], under different monetary regimes: the central bank can either caring about price stability only (γ= 0) or alternatively put a positive weight on output stability (γ > 0).

[10] Figure 5 shows the results of the simulations with the same random-seed. Indeed, results are consistent and robust whatever the random seed chosen.

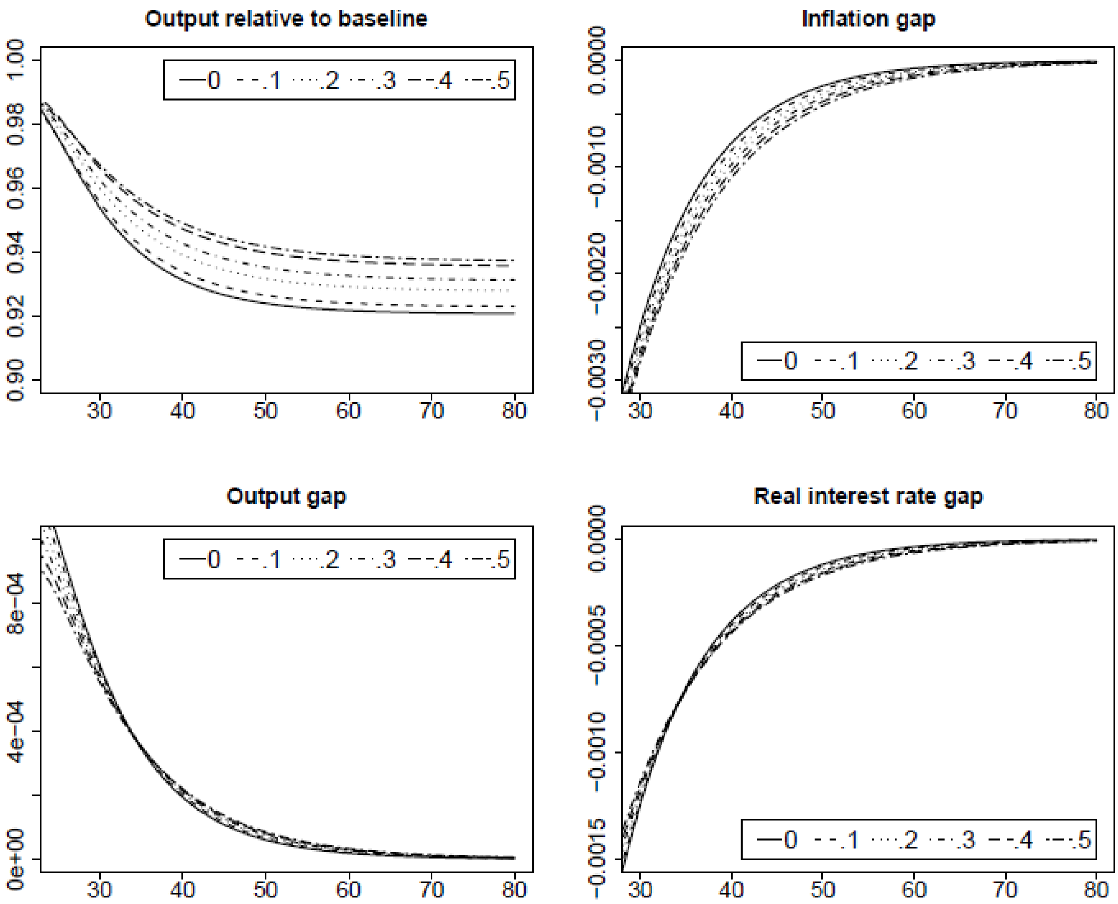


Figure 2.3: Permanent effects of temporary shocks with different monetary policy responses (different value of γ).

The same positive shock to $\hat{\varepsilon}_1$ has a different impact on final output according to the different weight put on output stability by the central bank: the hysteresis effect is more consistent in cases of slow reaction by the central bank, since aggregate demand falls sufficiently to induce some firms to permanently exit from the market and stabilize output downwards. Monetary policy has therefore a long run non neutral effect to the extent that it does not only affect the shape of the business cycle but also the final equilibrium, especially in cases of asymmetric reaction: stability-oriented in case of positive shocks and disinflation-oriented in case of negative shocks (Schettkat & Sun, 2009). The same applies for fiscal policy: to the extent that the central bank does not neutralize immediately a negative fiscal shock through a lower interest rate, the effect on output of a restrictive fiscal policy can be negative both in the short and in the long run

.

2.3.2. Policy effectiveness in linear hysteresis-augmented "new consensus" models

In standard "new consensus" models, as long as potential output is kept constant by assumption, a positive or negative output gap can only trigger a change in inflation, consequently fiscal policies are always inflationary and monetary policies always stabilizing, unless the *zero lower bound* is reached and positive fiscal policies become necessary to stabilize the economy (Snowdon & Vane, 2005). Lavoie (2006) and Fontana & Passarella (2014) show that this conclusion must be rejected in case of a permanent demand shock if we assume that potential output is a linear function of both past potential output and current output according to equation (10), which is a simple rearrangement of equation (1):

$$Y_t^p - Y_{t-1}^p = \Phi(Y_{t-1} - Y_{t-1}^p) \tag{10}$$

With $0 < \Phi < 1$. A positive shock to fiscal policy that is not immediately neutralized by the central bank through a higher real interest rate would lead to a permanent increase in real output, as long as potential output adjusts upwards through equation (10), the output gap goes back to 0 and inflation stabilizes back to the targeted rate.

We simulate the model by Lavoie (2006) assuming proportionately higher parameters with respect to Fontana & Passarella (2014), in order to accelerate the process of convergence, and assuming two different scenarios: the first scenario implies a permanent shock to ε_1 which is not neutralized by the central bank, while the second scenario implies a temporary shock to ε_1, still not neutralized by the central bank[11]. Eventually we compare the results with a standard "new consensus" model that assumes equation (6) instead.

[11] In the New Consensus models, the central bank neutralizes demand shocks through the natural rate of interest. Since the exogenous and stochastic shock ε_1 is, by assumption and by construction, a non-anticipated (fiscal policy) shock, it does not affect the natural rate of interest. A permanent exogenous shock to ε_1 is therefore interpretable either as a non anticipated long lasting shock or as a correctly anticipated but not neutralized shock. For the same reasons, a temporary shock to ε_1 must be interpreted either as a non anticipated temporary shock or as an anticipated structural shock that is neutralized through the natural rate of interest (in this case the central bank will identify the permanent stochastic shock ε_1 as a increase in the structural disturbance g_0).

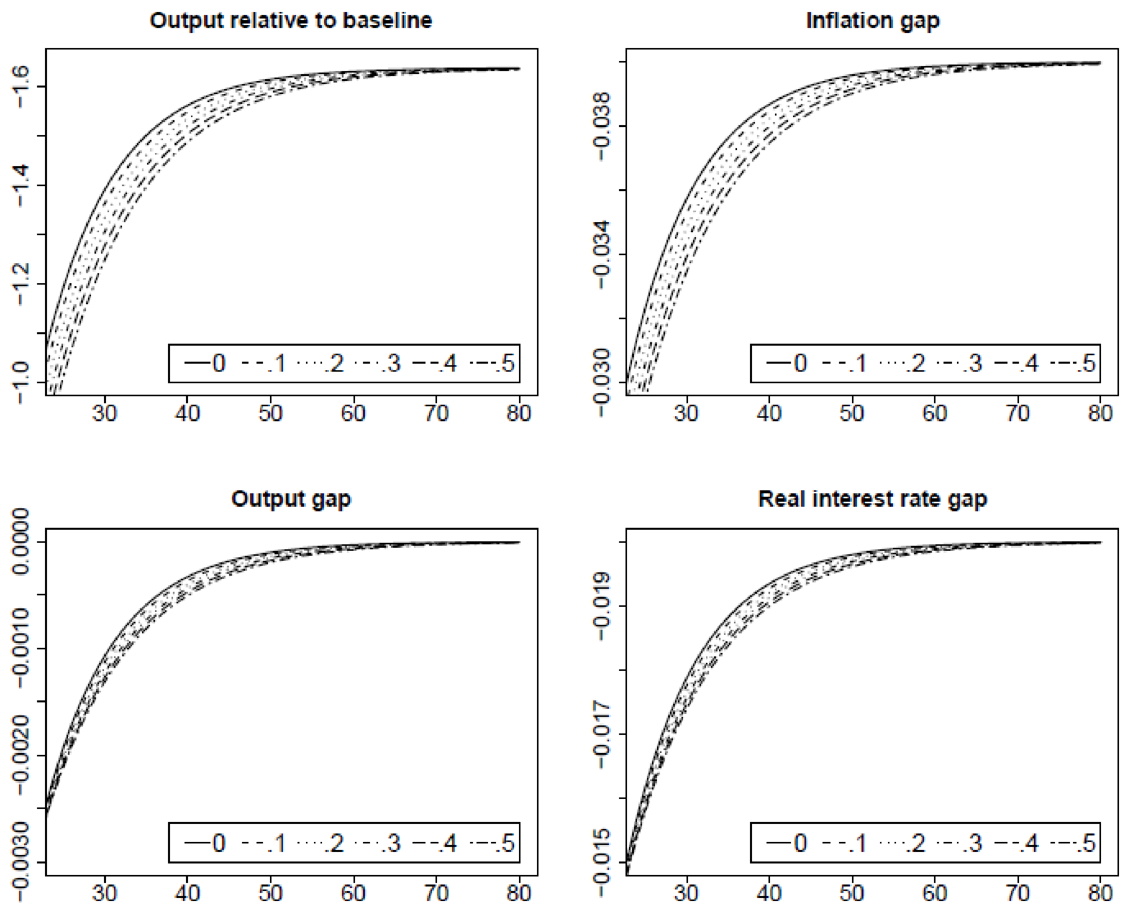


Figure 2.4: permanent effects of permanent shocks with linear hysteresis and different monetary policy responses (different value of γ)

Consistently with Fontana & Passarella (2014), the first scenario in figure 2.4 shows that a permanent shock to ε_1, when potential output is endogenous according to equation (10), implies a permanent impact on output and potential output. The reason is that, by construction of the model, the stochastic shock does not affect the natural rate of interest even if it persists. Consequently the central bank will not be able to properly estimate the "real" natural rate of interest and will observe a lower inflation rate and a lower-than-natural interest rate when real output will eventually adjusts to potential output.

This result cannot be found in a standard "new consensus" model. For instance, figure 2.5 shows the result of the same shock when equation (10) is replaced by equation (6): the permanent shock to $\hat{\varepsilon}_1$ implies a lower inflation rate, a lower rate of interest with respect to the natural rate but the same equilibrium output.

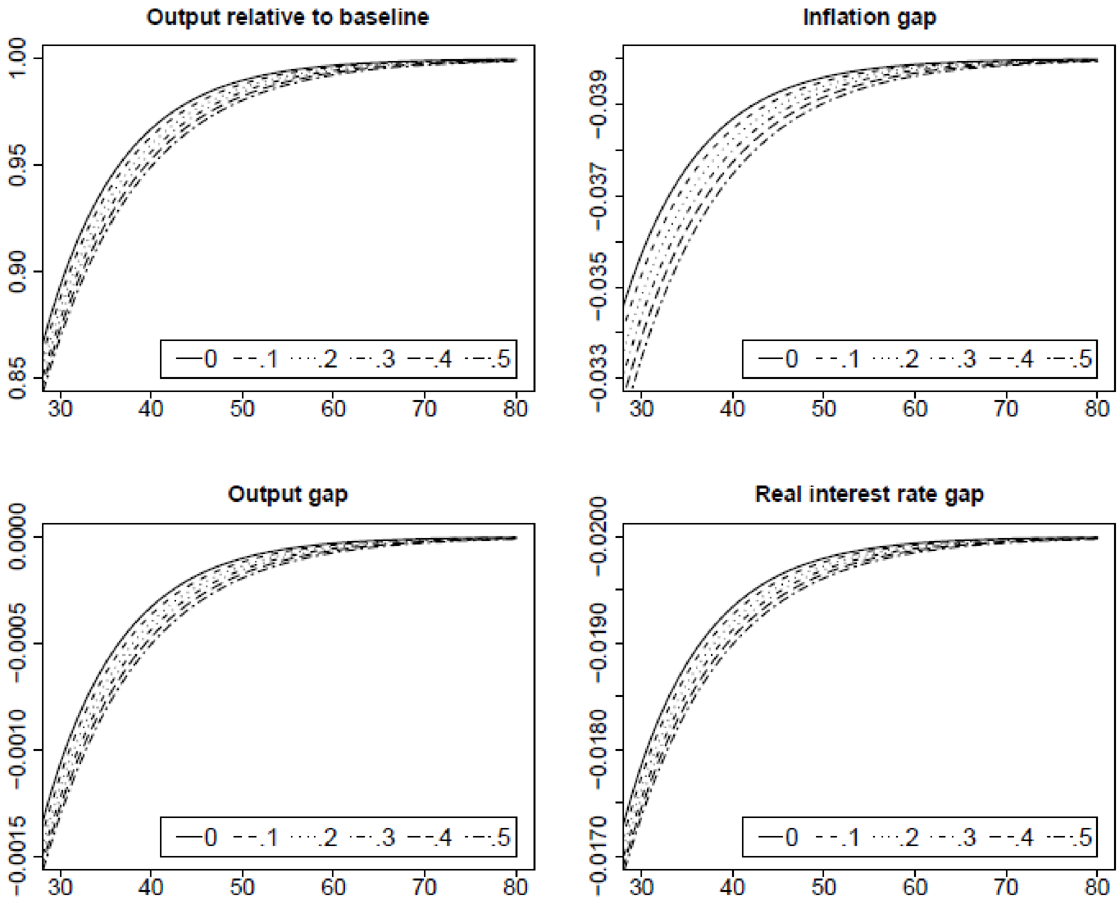


Figure 2.5: Temporary effects of permanent shocks with asymptotic stability of potential output and different monetary policy responses (different value of γ)

In this case, even though the current interest rate is different from the improperly estimated natural rate and inflation is lower than the targeted rate, potential output will not vary at all (again, by construction). The same does not apply, however, if we simulate a temporary shock to $\hat{\varepsilon}_1$. Figure 2.6 shows that although potential output is endogenous according to equation (10), as long as the shock is only temporary there is no permanent effect on real output: the negative initial shock implies an upwards adjustment of potential output, as soon as the positive shock fades out potential output readjusts downwards up to the initial equilibrium. A temporary negative shock is not able to change the structure of the economy as long as the central bank, sooner or later, neutralizes it through a lower "natural" rate of interest or to the extent that it fades out automatically. This result, which is also shown in Kienzler & Schmid (2014) and analytically proved in Lavoie (2006), is perfectly explainable by the linear nature of equation (10) and refers to the so-called "super-reversibility" property of linear models of hysteresis: a sequence of positive and negative shocks of same amplitude imply a sequence of positive and negative linear movements of output that are mutually offsetting.

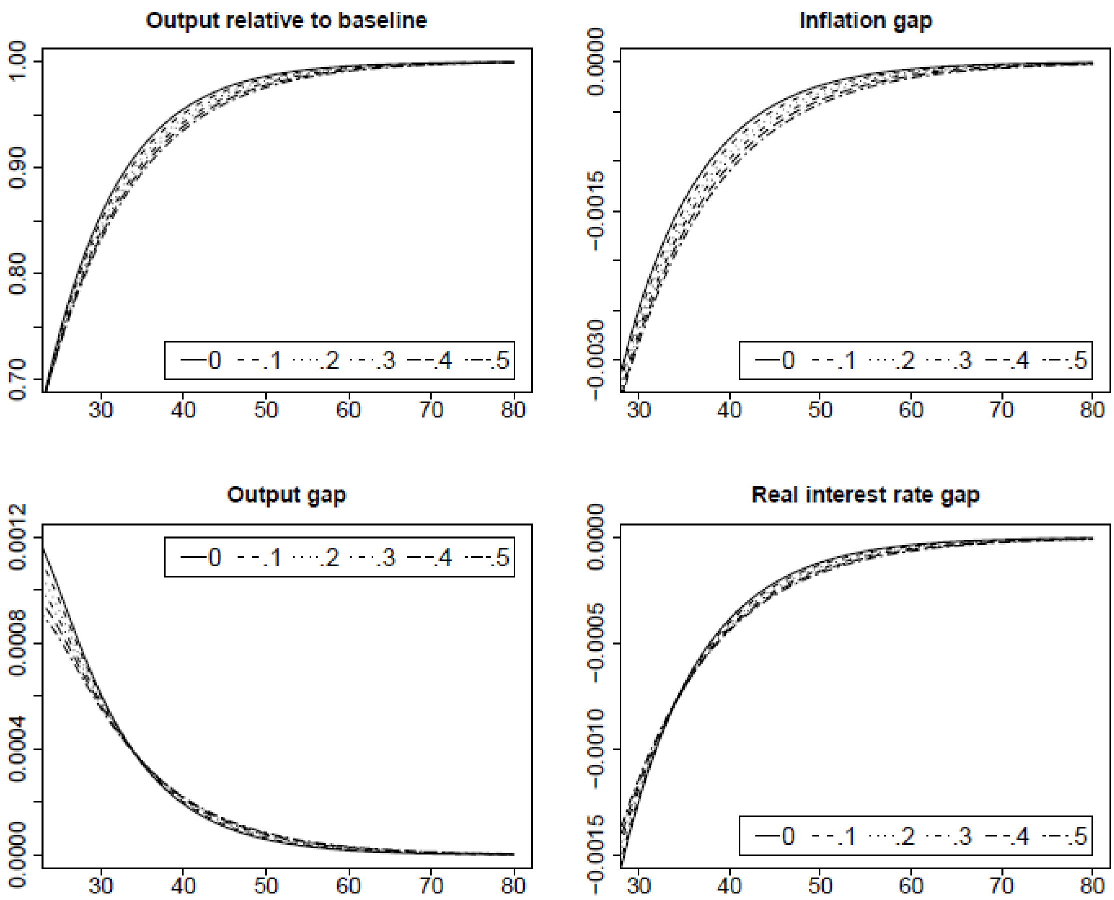


Figure 2.6: Temporary effects of temporary shocks with linear hysteresis and different monetary policy responses (different value of γ)

In particular, the negative initial shock is offset by the subsequent positive shock implied by the central bank's monetary reaction, namely the fall in the interest rate as a consequence of falling inflation. The long run behavior of the system is consequently equivalent to the long run behavior of standard "new consensus" models that assumes equation (6): the real output goes back to the original level as soon as the temporary shock is over (figure 2.7).

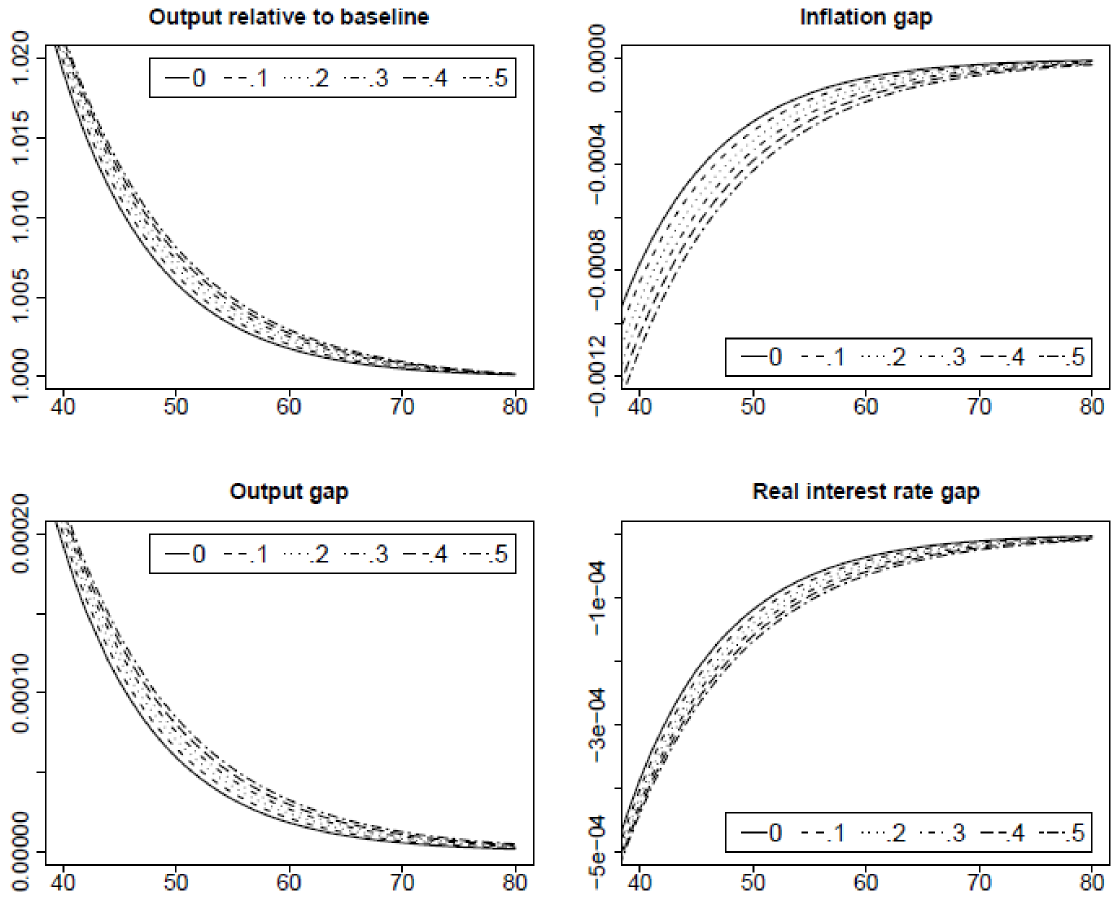


Figure 2.7: Temporary effects of temporary shocks with asymptotic stability of potential output and different monetary policy responses (different value of γ)

Hence, fiscal and monetary policies have a long run effect on real output when potential output is a linear and increasing function of the output gap only if the central bank is willing to accept a rate of inflation different from the target. If we assume instead that $E(\varepsilon_1) = 0$ and that the central bank rigorously tracks the targeted rate of inflation, positive or negative shocks (including fiscal policy shocks) can only affect the business cycle but they cannot affect the long run equilibrium. This result can also be obtained by assuming that equation (10) is a random walk by setting $\Phi = 1$, according to the Blanchard & Summers (1986) definition of hysteresis.

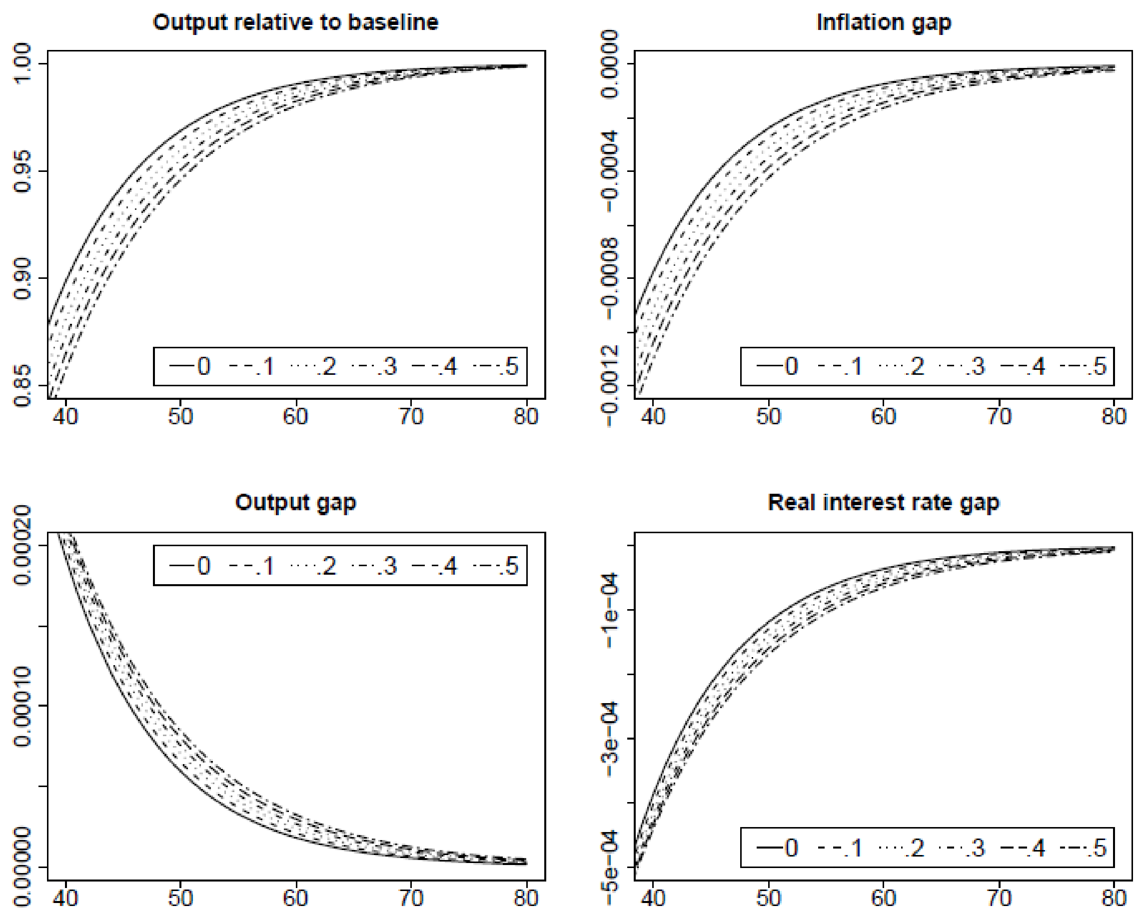


Figure 2.8: Temporary effects of temporary shocks with unit root hysteresis and different monetary policy responses (different value of γ)

As shown in figure 2.8, by introducing a unit root in equation (10) we obtain the same conclusions that would be obtained by setting $\Phi < 1$. The reason is that in standard models of unit root persistence, unemployment hysteresis implies that inflation stabilizes at a higher or lower level when respectively unemployment stabilizes at a lower or higher level. In the "new consensus" model, however, the reaction function of the central bank explicitly rules out this possibility, since a rate of inflation higher or lower than the targeted level implies a higher or lower rate of interest that adjusts output and potential output to the long run equilibrium. In other words, the monetary rule of the central bank prevents that the economy might stabilize at steady rates of inflation different than the targeted one and, thereby, that the economy might exhibit long run effects because of temporary demand shocks. It is the central bank behavioral function that explains why linear models of "hysteresis" cannot ultimately account for the persistence of the effect (on output) beyond the cause that generated it (the exogenous demand shock), i.e. hysteresis, in "new consensus" models.

2.4. Economic policy implications of “genuine” hysteresis and concluding remarks

According to the paradigm of asymptotic stability, upon which the standard “new consensus” model is built, the system has no long run memory of past shocks: to the extent that the central bank adopts the optimal monetary policy rule (Taylor, 1996; Clarida et al, 1999; 2000; McCallum, 2001; Woodford, 2001, 2003) recessions or booms can only have temporary effects until the system stabilizes back around its unique and asymptotically stable equilibrium, which is the NAIRCU. Discretionary fiscal policies are in this framework seen as destabilizing or at least as useless (Taylor, 2000B).

Introducing hysteresis through a linear function like equation (10) does not change substantially the economic policy conclusions: as long as demand shocks are only temporary and not systematic, introducing linear hysteresis will only affect the short run equilibrium and the speed of convergence towards the unique long run steady state. Indeed, to the extent that the central bank is committed to price and output stability, the optimal monetary policy rule is still effective in stabilizing the economy, demand shocks and fiscal policies can be perfectly neutralized. This conclusion is valid also by modelling equation (10) as a random walk, consistently with the new-Keynesian literature of hysteresis (Blanchard & Summers, 1986; Ball et al, 1999; Ball, 2009), unless a discontinuity is introduced via the price equation (Palacio-Vera, 2009). In this case, even though potential output adjusts linearly to aggregate demand, temporary demand shocks might have permanent effects on the long-run trend.

According to the “genuine” hysteresis-augmented “new consensus” model developed in this chapter, hysteresis is a more general paradigm consistent with both stationary and non-stationary trends (Amable et al, 2004). For instance, the effect of negative or positive shocks, whatever their amplitude, always depends on the relative position of firms with respect to their “inaction zone” and can consequently result in either temporary or permanent changes in the contingent equilibrium. Remanence, for instance, implies that the amplitude of a shock is not a sufficient information to determine whether there will be hysteresis or not: the history of the system, that is the sequence of past shocks, is also an important source of information in order to determine how the economy will respond to future shocks. In particular, temporary demand shocks have permanent effects if the system is caught in a moment of relative *fragility,* when most firms are within their “inaction zone”. Furthermore, remanence implies that long lasting or deep recessions are likely to trigger a permanent loss of potential output and higher costs of recovering, since the number of firms that decide to exit from the market is increasing in the amplitude of the shock. Consequently, the cost of recovering potential output losses in models of *genuine* hysteresis is higher than the cost of recovering potential output losses in a unit/zero root framework with "super-reversibility" or in a asymptotically stable framework with a demand-independent potential output.

By simply modelling firms' entry and exit decisions as non-linear and discontinuous according to two switching thresholds, consistently with equation (8), temporary shocks do not cancel out even though the central bank identifies the shock as a structural shock and adjusts the "natural" rate of interest. The existence of sunk costs and, in particular, the existence of a "inaction zone" that leads firms not to change their strategy, whatever the strategy is, allows reconsidering the asymptotic stability of equilibria and the relevance of the traditional steady state analysis based on the concept of a stable *non-accelerating inflation* long run equilibrium. Indeed, if temporary and cumulatively neutral shocks can have permanent effects, there is no longer a long run equilibrium that can be considered as a "center of gravity". Moreover, demand policies become crucial for determining the endogenous and historically contingent equilibria. Fiscal policies, for instance, are neither destabilizing nor useless, since they substantially contribute to determine the long run equilibrium: a discretionary and positive fiscal policy that raises demand, even temporary, might trigger a permanent increase in output without permanent pressures on inflation. The same applies for monetary policies: the weight put on output stability affects both the speed and the pace of adjustment, a result that cannot be found in standard or in linear-hysteresis augmented NC models. The long run neutrality proposition is radically rejected, consistently with number of empirical evidence (Ball et al, 1999; Stockhammer & Sturn, 2012; Cerra et al, 2009; Schettkat & Sun, 2009).

The simplicity of the model, however, is not without costs: this model assumes implicitly that labor productivity is constant and potential output is upwardly bounded: there is a fixed number of firms choosing between enter or exit from the market with a constant capital stock. By assuming that firms do not only decide between staying or exit from the market but also between varying or not productive capacity in a dynamic framework with non-constant labor productivity and capital depreciation (Abel & Eberly, 1999; Bertola & Caballero, 1994), the conclusion of the model might potentially change. For instance, the dynamics of the model might be dominated by low sunk costs firms that would accumulate more capital and consequently grow in size, especially if demand shares depend on capital stock (hence on size). In this case, everything else equal the hysteresis effect would tend to cancel out progressively. Furthermore, the model assumed exogenous and fixed switching values, two assumptions that are common to models of "genuine" hysteresis although probably limiting when it comes down to model and explain the evolution of firms' decision processes.

Further developments of the model might try to relax some of these assumptions, namely the exogeneity of switching values, and introduce a dynamic investment function. It could be interesting for instance to focus on capital accumulation and labor productivity dynamics. Indeed, although the model is restricted to a set of specific assumptions, the model of "genuine" hysteresis *per se* is pretty flexible to more complex assumptions concerning the input, the output and the switching values, and it owns a set of mathematical and "philosophical" properties that traditional steady state models neglect by construction, namely the influence of time and history on equilibrium determinacy and the existence of non-linearity and discontinuity in macroeconomic adjustments. Therefore, the paradigm of "genuine" hysteresis represents, from a theoretical and epistemological point of view, an interesting alternative to both unit root and traditional steady state macroeconomic models.

Appendix 2.1: parameters' value

Parameters	Values
β	0.5
η	0.5
ξ	0.5
γ	[0, 1]
ϕ	0.5; 1
g_0	0.01
π_T	0.02
$\hat{\varepsilon}_1$	0; 0.01
a	~U(-1, 1)
b	~U(-1, a)

3. Sunk costs effects, discontinuous investment decisions and fully endogenous degrees of capacity utilization. A Post-Keynesian micro-foundation[12]

3.1. Introduction

Chapter two developed a "new consensus" monetary model with *genuine* hysteresis in order to show that standard conclusions concerning the existence of "natural" equilibria and the consequent long run vertical Phillips curve do not hold any longer when discontinuous adjustments of capital stock to demand shocks are introduced. For instance, the existence of a *zone of inaction* in firms' investment decisions implies that transitory shocks have permanent effects. Consequently, steady inflation and full capacity utilization are consistent with a *range* of different and unpredictable output levels rather than a unique long run *centre of gravity*. In order to do so, the model kept the standard assumptions of the "new consensus" framework, namely the hypothesis of an *accelerationnist* Phillips Curve, the existence of a *natural* rate of interest correctly forecasted by the Central Bank and the neoclassical inter-temporal consumption theory relating consumption decisions to the interest rate in an infinite horizon.

From a Post-Keynesian perspective, however, these assumptions are particularly controversial. The accelerationnist Phillips curve, which is at the heart of the historical controversy between Keynesian and neoclassical economists, lies for instance on the specific assumption that agents are fully rational and do not exhibit monetary illusion. As a consequence, an increase in expectations of inflation implies an equal increase in wages. Assuming, however, that workers only bargain a nominal wage, and that in some sectors unions are not sufficiently strong to obtain an increase in the money wage proportional to the expectations of inflation (Tobin, 1972), a positive or negative unemployment gap (which is the difference between actual and *natural* unemployment) does not imply rising or falling inflation but only a higher or lower steady rate. This assumption, however, is crucial in the model: if expectations of inflation are only partially turned into higher wages and the costs of

[12] This chapter has been published in the "Economic Modelling" review with the title: "Investment Hysteresis and Potential Output in a Post-Keynesian-Kaleckian Agent-Based Approach". The article can be read at the following electronic address: http://www.sciencedirect.com/science/article/pii/S0264999315001777

rising economic activity are strictly finite, Setterfield (2004) shows that there is a long run trade-off between the rate of inflation and the rate of growth that prevents the central bank from fixing at the same time these two conflicting goals, a target rate of inflation and a target rate of growth. The existence of a *natural* rate of interest is also a sensitive assumption.

The Wicksell's *natural* rate of interest corresponds to the specific rate that equalizes aggregate savings and aggregate investments in a simplified barter economy. Holding the existence and the stability of the central bank's predictions of this long run interest rate in a monetary production economy is however not plausible, especially when introducing a certain degree of market power of the banking system and the existence of a liquidity preference (Smithin, 2004; Arestis and Sawyer, 2004). Moreover, assuming the existence of a determined long run *natural* rate of interest rules out the existence of a conflict in income distribution in which the interest rate is a fundamental part of the story. Brancaccio & Fontana (2013) challenge, for instance, this *conventional wisdom* about the neutrality of the interest rate in the distributional conflict, and propose to replace the Taylor rule with an alternative monetary rule which is more consistent with a Post-Keynesian theoretical framework. This assumption of a *natural* rate of interest correctly foreseen, however, is crucial to the model: as shown in chapter 2 (section 2.4.2), assuming at the equilibrium a rate of interest different from the *natural* rate implies a rate of inflation different from the target rate, which is however a necessary condition for a steady state in the "new consensus" framework.

The neo-classical inter-temporal theory of consumption implicit in the IS equation, which is derived by assuming households' optimal savings decisions (Clarida et al, 1999), is also a consequence of the fundamental axiom of full rationality, which implies a constant optimizing choice between consumption and savings depending on the real rate of interest. Furthermore, since in the standard three equations "new consensus" model there are no investments and government expenditure is constant, the real interest rate is supposed to play a stabilizing role only by affecting consumption decisions. One of the central critiques of Keynes in the *General Theory* was explicitly about the neoclassical theory of consumption. According to Keynes (1936), households' consumption decisions do not depend on the real interest rate but on a relatively stable propensity to consume out of income depending, among others, on psychological motives. In this framework, the real interest rate affects aggregate demand via investments, not via consumption. Ruling out investments from aggregate demand would imply a very low, if any, influence of the real interest rate on output. Nevertheless, this assumption is also crucial to the stability of the model. By assuming a low elasticity of the output gap with respect to the interest rate would seriously undermine the stability of the model (Setterfield, 2007).

A further assumption of the "new consensus" framework that is particularly controversial in a Post-Keynesian perspective is the characterization of the steady state as full capacity utilization equilibrium. This assumption is implicit in the Phillips curve equation, according to which there is only one rate of capacity utilization consistent with stable inflation, the *NAIRCU*. For instance, the level of output corresponds by definition to the degree of utilization of the productive capacity installed, while *potential output* corresponds, according to the Phillips curve equation, to the degree of utilization of the productive capacity installed that is consistent with steady inflation, hence the NAIRCU (Gordon, 1998; Nahuis, 2003):

$$\begin{cases} Y = uY^{pc} \\ Y^{p} = u^{naircu}Y^{pc} \end{cases}$$

The characterization of the equilibrium as a steady inflation fixed point requires that the level of output be equal to potential output, $Y = Y^{p}$, which implies $u = u^{naircu}$.

There is a historical debate among the post-Keynesian, and between the post-Keynesian and the Marxist/Sraffian schools, concerning the long run validity of the concept of *fully adjusted position* (Vianello, 1985). On one hand, the Marxist and Sraffian schools argue that in the long run the rate of capacity utilization must converge to a *normal*, or *planned* degree of capacity utilization, hence to a *fully adjusted position* (Committeri, 1986; Skott, 1989; Dumenil & Levy, 1995; Cesaratto et al, 2001). The mechanisms of convergence can be of different kind. According to Dumenil & Levy (1995), it is real output that converges towards *normal* output through a monetary policy mechanism which is very similar to the "new consensus" framework: when real output rises above normal output, the consequent inflationary pressure triggers a restrictive monetary policy that dissuade firms from investing and brings back output on its normal level. When, on the other hand, real output is below normal output, the central bank will lower the interest rate in order to avoid a deflationary pressure and will consequently encourage firms to invest by fueling a recovery until the real output goes back towards its normal level (Lavoie, 1996). According to Cesaratto et al (2001), the process of adjustment is slightly different: when the rate of capacity utilization increases above the *planned* degree, firms will accumulate more rapidly in order to adjust productive capacity to the higher level of demand. When, on the other hand, the rate of capacity utilization falls below the planned degree, firms will reduce their capacity-creating investments in order to adjust productive capacity downwards until the lower capacity is normally utilized. The counter-cyclical role of autonomous expenditures is the key mechanism ensuring the adjustment of the rate of capacity utilization to the normal degree: when utilization is below the normal rate, investments fall and autonomous expenditures increase, consequently the fall in productive capacity is faster than the fall in aggregate demand induced by falling investments. When, on the other hand, the rate of capacity utilization is above the normal degree, investments increase and autonomous expenditures fall, consequently the rise of productive capacity is faster than the rise in aggregate demand (Lavoie, 2014). The consequence, according to the authors, is that:

"in the process of accumulation the productive capacity of the economy gravitates towards a fully adjusted supermultiplier in which the capacity follows the trend of effective demand and the degree of capacity utilization is equal to the planned one." (Cesaratto et al, 2001: p. 18)

Opposed to this theory of fully adjusted position, some Post-Keynesians and Sraffian authors argue that the rate of utilization can be lower than the normal rate also in a long run horizon for different reasons. According to Kurz (1993), firms are always subject to demand constraints; hence, even though they know their normal rate of capacity utilization, they will not necessarily be able to reach it if demand is insufficient to produce a quantity of output consistent with that rate. Furthermore, to the extent that firms usually tend to keep idle capacity for macro- and meso-economic considerations, including the capacity to face unexpected peaks of demand and the possibility to raise production as a threat to potential competitors (Lavoie, 1996; Palumbo & Trezzini, 2003), the rate of capacity utilization might be lower than the *normal* one without triggering capital scrapping. Producing at a lower than *normal* rate of capacity utilization, moreover, is not necessarily a violation of the cost-minimizing principle. According to Lavoie (2014), to the extent that a firm can decide not to run some plants at all and fully run the others, a lower than *normal* rate of capacity utilization can be consistent with costs minimization. According to Nikiforos (2013), to the extent that a firm can decide among different production techniques with different shifts and different number of machines to be run, the cost-minimizing degree of capacity utilization can be endogenous, especially in presence of economies of scale. As a consequence, rather than converging towards a normal degree, we would rather observe the actual rate of capacity utilization of firms gravitating within a range of normal degrees (Dutt, 1990; Lavoie, 2014). Also Palumbo & Trezzini (2003), who reject the assumption of a steady state rate of capacity utilization, either normal or non-normal, conclude that:

"(…) in the first place, the very process of adjusting capacity to demand requires the degree of utilisation diverging on average from the normal one for a rather long interval of time before the need is felt by firms to adapt their capacity - which confirms what we said in the previous paragraph about the impossibility of considering normal utilisation as the average condition of the system." (Palumbo & Trezzini, 2003: p. 15-16).

Consistently with this second stream of thought that rejects the assumption of a normal degree of capacity utilization as a *centre of gravity*, chapter 3 develops a standard Post-Keynesian/Kaleckian (PKK) model of growth and distribution characterized by a multiplicity of heterogeneous firms who invest according to a discontinuous function of the rate of capacity utilization, without any predetermined reference to a *normal* degree.
There are many advantages of this model with respect to the "new consensus" framework. On one hand it already includes investment and savings functions that are consistent with the Keynesian theory of consumption and investment. Furthermore, it does not include any reference to whatever *normal* rate of interest by assuming, on the contrary, that the rate of profit is fully endogenous. On the other hand, it does not impose any constraint on the output gap, allowing a larger feedback of output (investment decisions) to input (the rate of capacity utilization).

In particular, the neo-Kaleckian model of growth and distribution (Rowthorn, 1981; Dutt, 1984; Lavoie, 1996) is a three equations model including an investment function that relates the rate of capital accumulation to the rate of utilization (or the rate of profit), a saving function relating saving decisions to a fixed propensity to save out of profits and a profit function relating the profit rate to the full-capacity output to capital ratio, the rate of capacity utilization and the profit share:

$$\begin{cases} g^i = \frac{I}{K} = \alpha_0 + \alpha_1 u \\ r = \frac{\Pi}{K} = \frac{\Pi}{Y}\frac{Y}{Y_p}\frac{Y_p}{K} = \pi u v \\ g^s = \frac{S}{K} = sr = s\pi u v \end{cases} \quad (1)$$

Where I is the level of investment, K is the capital stock, α_0 and α_1 are parameters representing, respectively, animal spirits and the propensity to invest out of the rate of utilization, u is the rate of utilization, r is the rate of profit, Π is gross profits, Y is output, Y_p is full-capacity output, π is the profit share, v is the full-capacity output to capital ratio, s is the propensity to save out of profits and S is gross savings. In this model, the equilibrium rates of capacity utilization, u^*, and capital accumulation, g^*, emerge as endogenous variables dependent on the structural parameters of the investment function, α_0 and α_1, and on the structural parameters of the saving function, π, v and s. For instance, by imposing the equilibrium condition according to which investments equal savings, we get the following equilibrium equations:

$$\begin{cases} u^* = \frac{\alpha_0}{s\pi v - \alpha_1} \\ g^* = \alpha_0 + \alpha_1 u^* \end{cases} \tag{2}$$

A graphical representation of the model helps to analyze its main properties:

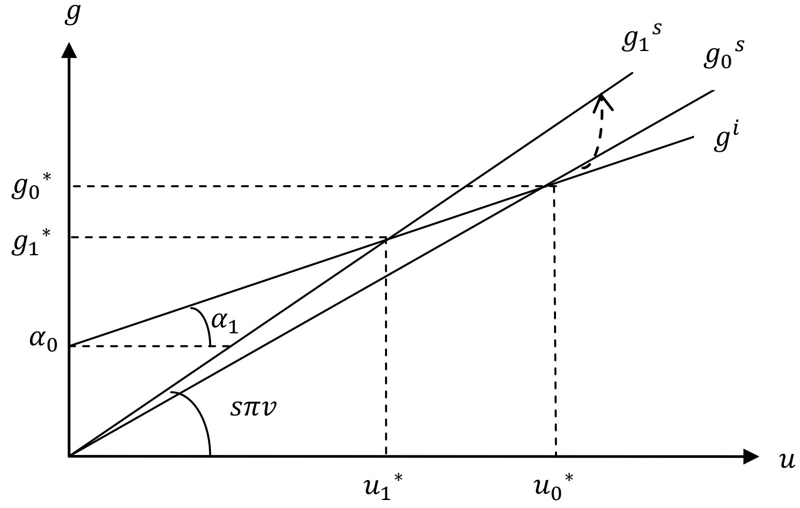


Figure 3.1: representation of the paradoxes of thrift and costs in the neo-Kaleckian model of growth

An increase in the profit share (i.e. a fall in the real wage at constant labor productivity), rather than increasing employment and output will raise the savings function and lower the equilibrium rates of utilization and accumulation, consistently with the "paradox of costs" (Rowthorn, 1981). An increase in the propensity to save out of profits, rather than increasing investments and ouput will also raise the savings function and lower the equilibrium rates of utilization and accumulation, consistently with the "paradox of thrift" (ibid). The paradoxes of profits and thrift are based therefore on the assumption that the rate of utilization is endogenous, and that a change in the structural parameters of the equation implies a change in the final equilibrium.

The model in chapter 3 represents a micro-foundation of the savings and investment functions of the neo-Kaleckian model of growth and distribution. Consistently with section 2, it assumes that firms are subject to uncertainty and sunk costs (Dixit, 1989). Nevertheless, when they decide to enter into a market they do not only engage in a one-for-all investment decision, but in a series of investment decisions that imply a certain rate of growth of productive capacity. In other words, firms do not target a specific level of capital stock, but they rather target a *range* of desired rates of growth of productive capacity in a long time horizon. According to Crotty (1993), for instance, because of sunk costs and worldwide competition firms are *coerced to invest*, because if they do not invest they risk exiting from the market. Furthermore, to the extent that *sunk costs effects* (Arkes & Blumer, 1985; Garland, 1990) push firms to continue investing in a certain project in which they already invested, the rate of utilization must be sufficiently low or sufficiently high to induce a change in investment plans, by creating a range of rates of capacity utilization consistent with the stability of a planned degree of growth (see section 4 for a larger development of the *coerced investments* and *sunk costs effects* arguments). Consequently, firms' investment decisions depend discontinuously on the degree of capacity utilization, according to a disinvestment and an investment thresholds that take into account heterogeneous sunk costs and heterogeneous expectations. By introducing a discontinuous investment function of this type, transitory shocks to the propensity to save out of profits, to the real wage and to *animal spirits* imply permanent shocks to the rate of utilization, the rate of capital accumulation and the rate of unemployment.

The novelty of this model with respect to the literature on *genuine* hysteresis is that it does not assume a cumulatively neutral input that produces a *hysteretic* output, it rather *obtains* a hysteretic input that produces a hysteretic output because of transitory shocks to the propensity to save out of profits, to income distribution and to firms' animal spirits. Hysteresis in the rate of capacity utilization (the input) can be characterized as an *emergent* property of the model, which implies the long run validity of the paradoxes of thrift and costs despite the transitory nature of shocks. Consequently, the model provides a plausible justification for rejecting the assumption of a unique and fixed *normal* degree of capacity utilization, in favor of a *range* of rates of capacity utilization and capital accumulation around which the economy might fluctuate persistently. Furthermore, it provides an explanation of how transitory demand shocks can have permanent effects on the long run trajectory of the economy, consistently with the empirical evidence of stably lower rates of growth, lower rates of inflation and higher rates of unemployment in most European countries after the 2008' financial crunch. The remainder of the chapter is organized as follows: section 3.2 is a literature review about the structure and the fundamental properties of the Kaleckian model of growth and distribution; section 3.3 presents a simple agent-based PKK model of growth and distribution with *genuine* hysteresis; section 3.4 shows how the system reacts when submitted to aggregate demand shocks; section 3.5 concludes.

3.2. A simple path-dependent agent-based PKK model of growth and distribution

Applications of the standard genuine hysteresis model to economics are mainly about international trade on the one hand (Amable et al, 1995) and unemployment on the other hand (Piscitelli et al, 2000; Cross et al, 1998; De Peretti & Lang, 2009). Cross et al (2012) extended the model of genuine hysteresis to potential output. In models dealing with unemployment, the economic intuition relies on the existence of sunk costs in hiring decisions that make firms adjust discontinuously to price. While in models dealing with international trade, the main focus is about sunk costs in investment decisions and real exchange rate fluctuations (Dixit, 1989).

Consistently with the standard model of *genuine hysteresis* as applied in sciences like physics and biology, however, most[13] of these models assume an exogenous input in order to focus on the emergent discontinuity of output to exogenous input shocks, and neglect the difficult issue of the feedback mechanisms running from the output to the input. This hypothesis, which can make sense under some circumstances for some systems in physics, might prove problematic in economic systems. For example, if demand increases, investment may also increase and it does not really make sense to suppose that this increase will not have any influence on demand. Therefore, the feedback should be taken into consideration and this is precisely what the model does.

In the wake of Cross et al (2012), this model of genuine hysteresis investigates the economic conditions that are required to have persistent suboptimal equilibria in unemployment and capital accumulation, despite the temporary nature of macroeconomic shocks. Nevertheless, the input is fully endogenous and it is represented by aggregate demand, proxied by the rate of utilization of productive capacity, while the output variable is the rate of capital accumulation. Since investment decisions of firms imply production decisions by other firms, capital accumulation affects effective demand and, as a

[13] To our knowledge, Piscitelli et al (2000) is the first and only attempt to produce a model of *genuine* hysteresis with endogenous input.

consequence, the rate of capacity utilization in the economy (this is the way in which the feedback operates).

The PKK-ABM model of growth and distribution that follows assumes discontinuous investment functions and introduces a set of behavioural rules for agents (firms, workers and capitalists) that will affect the way they coordinate each other through investment and consumption decisions. The macroeconomic results obtained are suboptimal equilibria generated by the failure of coordination among agents whose micro-decisions are independent of equilibrium optimality conditions.

As most standard PKK models, this one assumes a closed and real economy. The government does not undertake any fiscal activity. Goods are produced with two basic factors of production, labour and capital, and the labour market is fully flexible in order to focus explicitly on the consequences of goods market dynamics on employment. More specifically, the length of labour contracts is one period only and workers' union can only set wages according to its bargaining power, but it cannot set the number of employees, which is chosen by firms according to their needs for production[14]. The production function is a Leontieff one with complementary factors and constant capital to output ratio. Therefore, employment dynamics will depend on the relative speed of capital accumulation with respect to labour productivity growth.

The economy is also supposed to be wage-led: an increase in the wage share will induce a higher rate of capital accumulation because of its positive impact on demand and a negative shock to the real wage will necessarily depress demand. Onaran and Gallanis (2012) have shown empirically that most countries in the world (and the world as a whole) are currently wage-led rather than profit-led. Note that in their study, the European countries that have suffered losses in permanent output mentioned earlier are all wage-led.

The model includes also some specific assumptions that do not necessarily characterize standard PKK models. Indeed, in this model there are two sectors, one for investment goods and the other for consumption goods. The rate of capacity utilization is to be considered as sector-specific: all firms belonging to the same sector have the same rate of capacity utilization, but each sector has its own rate of capacity utilization, according to consumption and investment dynamics. Therefore, the heterogeneity of firms implies different

[14] Obviously, in order to make the model more complex, it could be possible to introduce a negative relationship between the bargaining power of the unions and the level of unemployment. Since the focus is on the core of the model, this task is left to future research.

investment rules and different rates of capital accumulation in a common aggregate demand environment.

3.2.1. Sunk costs, strategic decisions and switching values

Investment decisions are generally taken in a genuinely uncertain environment (Keynes, 1921), and they imply sunk costs that cannot be recovered if the investment decision is reverted (Dixit, 1989). Generally speaking, firms invest in *productive* capital if expected returns exceed expected costs. However, to the extent that some costs are fixed and cannot be recouped if the investment fails (sunk costs), firms will require a minimum level of capacity utilization sufficiently high to make the risk of having net losses fully compensated. Furthermore, if a firm decides to invest but capacity utilization turns out to be lower than expected *ex post*, before disinvesting it will make sure that the costs of dismissing the excessive capital are lower than the costs of under-utilizing the whole capacity.

Formally firms' investment criterion is (see section 1.3.3.):

$$\sum_{t=1}^{n}(R(u_t) - C(u_t))e^{-rt} > \mu + SK \quad (1)$$

With $\mu = \sum_{t=1}^{n}\big(R(u^*{}_t) - C(u^*{}_t)\big)e^{-rt}$. *R* stands for expected income, *C* for expected variable costs, *u* for capacity utilization, *r* for the rate of time preference, *SK* for the sunk costs and μ for the expected profits of not to invest. The letters with a star indicate expected income, expected costs and expected rate of utilization if the investment is not undertaken.

The reason of this investment specification is quite intuitive: when the firm has to decide whether to increase or not to increase productive capacity, the expected profits must be higher than the sunk costs related to the new capital goods purchased and to the costs of pushing capacity utilization upwards. The variable μ, for instance, is expected to capture all the micro-, macro- and meso-economic reasons behind the decision of increasing or decreasing capacity utilization, namely the desire to push capacity utilization up to the costs minimizing rate, the possibility to rapidly satisfy peaks of demand by installing an excessive productive capacity and the strategic decision to keep idle capacity as a deterrent to new entrant firms (Kurz, 1986; Lavoie, 1996; Palumbo & Trezzini, 2003). Therefore, investment decisions adjust discontinuously to aggregate demand shocks according to the sensitivity to invest and according to the series of past shocks that affected firms' investment decisions in the past.

If a firm has already invested and has to decide whether to dismiss productive capacity or not, the expected costs of keeping the same productive capacity need to be higher than the costs of dismissing productive capacity, which are equal to unrecoverable costs and to micro-, macro- and meso-economic costs of over-utilizing productive capacity. Formally, firms' disinvestment criterion is the following:

$$\sum_{t=1}^{n}(R(u_t) - C(u_t))e^{-rt} < \mu - SK \tag{2}$$

Investment and disinvestment decisions of firms imply strategic considerations concerning the expected rate of capacity utilization and the ex-post costs of reverting investment decisions already undertaken; consequently, they are fundamentally not linear with respect to external shocks that affect the rate of capacity utilization. In particular, by defining the following equalities:

$$\begin{cases} \sum_{t=1}^{n}(R(u_t) - C(u_t))e^{-rt} = f(u_t) \\ (SK + \mu) = \zeta \\ (\mu - SK) = \Gamma \end{cases} \tag{3}$$

Both the investment and dismissing criteria can be formalized as direct functions of the rate of capacity utilization:

$$\begin{cases} f(u_t) > \zeta \quad if\ and\ only\ if \quad u_t > f^{-1}(\zeta) = a \\ f(u_t) < \Gamma \quad if\ and\ only\ if \quad u_t < f^{-1}(\Gamma) = b \end{cases} \tag{4}$$

Where $f^{-1}(\zeta)$ and $f^{-1}(\Gamma)$ are the inverse functions of $f(u_t)$[15]. Firms will invest whenever the rate of utilization is sufficiently high to make expected profits higher than expected costs, and do not invest whenever the rate of utilization is sufficiently low to make expected profits lower than expected costs.

3.2.2. Effective demand, expectations and the rate of capacity utilization

The rate of capacity utilization for firm *i* is equal to the ratio of production over productive capacity:

$$u_i = \frac{Y_i}{Y_i^p} \tag{5}$$

[15] For the sake of simplicity, $f(u_t)$ is a reversible function as $0 < u_t < u_F$, where u_F stands for the full rate of capacity utilization. This assumption implies that expected profits are monotonic and increasing with respect to the rate of capacity utilization when this latter lies below the full rate.

There are two sectors: firms can produce either consumption or capital goods. Although firms belonging to the same sector are heterogeneous with respect to their switching values (for investing or disinvesting) and with respect to their expectations, the model assumes that they all face the same relative demand, proportionally with their size: big firms will face a higher absolute demand with respect to small firms, but the rate of capacity utilization will be the same. Consequently, the rate of capacity utilization is a sector-specific variable: each firm faces the same rate of capacity utilization than all firms belonging to the same sector[16].

As regards expectations, the model assumes that firms behave consistently with a bounded, procedural rationality *à la* Simon (1972). Indeed, in a radical uncertain environment, where individuals take decisions according to the limited set of information they have, rational decisions are substituted with reasonable decisions, optimal choices with *satisficing* choices, rational expectations with experience-based *rules of thumb*.

Consistently with most of Keynesian ABM models (Seppecher & Salle, 2015; Dosi et al, 2013), firms estimate their future demand by looking at the variation of inventories: once the ratio of inventories over productive capacity, s_t, is equal to a *desired* reference ratio, s^*, firms will only produce the quantity of goods that they expect to be sold, $u_{e,t}$, which is equal exactly to the variation of inventories, $(u_t + s_{t-1} - s_t)$. Formally:

$$u_{t+1} = s^* - s_t + u_{e,t} = s^* - s_t + (u_t + s_{t-1} - s_t). \quad (6)$$

Expectations are sensitive to the discrepancy between the actual and the *desired* ratio of inventories over productive capacity, consistently with a basic adaptive expectations framework in which agents take decisions according to a simple rule-of-thumb based upon past experience. In particular, if the actual ratio of inventories over productive capacity increases over time, firms will interpret this excess of inventories as a lower-than-expected demand, and will revise expectations downwards by producing at a lower rate of capacity utilization. If, on the other hand, the actual ratio of inventories over productive capacity decreases over time, firms will interpret this insufficiency of inventories as a higher-than-expected demand and will revise expectations upwards by pushing the rate of capacity utilization. Eventually, if the actual ratio of inventories over productive capacity is constant

[16] The assumption of a unique rate of capacity utilization, however limiting, is made to focus on the way heterogeneous firms react to a same aggregate shock. The aim of this model is not to reproduce business cycles but rather to analyse how *equilibria* can permanently change in the wake of sectorial temporary shocks.

over time, firms will go on producing at the same rate of capacity utilization, since demand was exactely equal to production.

Besides this backward-looking criterion, however, production decisions also depend on a “irrational”, forward-looking component, which affects investment decisions and reflects the Keynesian idea of “animal spirits”. In particular, investment decisions are modelled as a function of an exogenous and constant component, which depends on firms’ “animal spirits”, plus an additional component which depends on the expected rate of capacity utilization. Therefore, when a firm is in equilibrium because the rate of stores over productive capacity is constant and equal to the desired ratio, and $u_{t+1} = u_{e,t}$, the rate of capacity utilization is the same over time but the level of production is constantly increasing according to the pace of capacity accumulation, which depends on the backward-looking component, the rate of utilization, and a forward looking component, animal spirits. As a consequence, if firm *i* decides to increase productive capacity and to produce in the future at the same rate of capacity utilization, the future level of production will be equal to the past level of production plus the expected increase in market demand, which is reflected in the decision to invest and increase productive capacity.

3.2.3. Investment decisions and capital accumulation

By recalling (3) and (4), investment and disinvestment decisions can be represented as fundamentally non-linear because of sunk costs and because of micro-, macro- and meso-strategic choices. Diagram in figure 3.2, inspired by Amable et al (2004)[17], illustrates this accumulation behaviour.

[17] The model in Amable et al (2004) is a model of international trade with the exchange rate as input and the export volume as output.

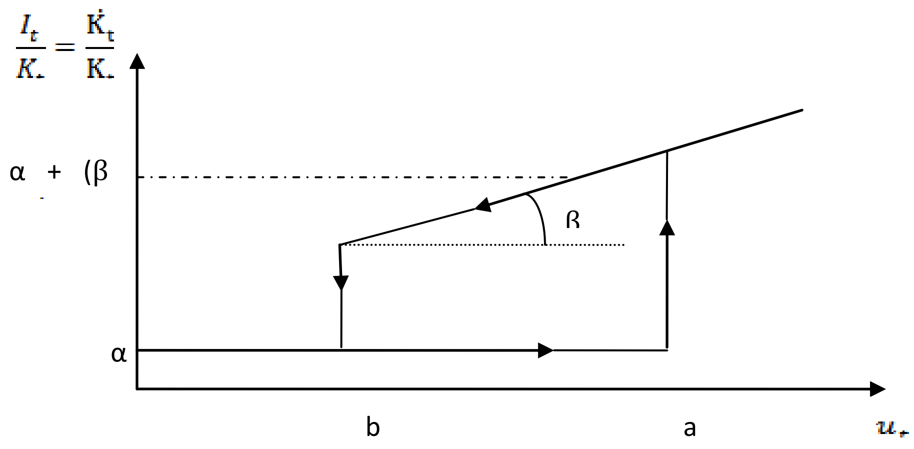


Figure 3.2: the rate of capital accumulation as a function of the rate of utilization

Investments in fixed capital at time *t* depend on the rate of capacity utilization, u_t: if *expected* net profits, which are a function of the rate of capacity utilization according to (3), are higher than *a*, firms invest an amount of fixed capital which is proportional to the rate of utilization.

However, even though the rate of utilization were to fall by making negative net profits, firms would not decelerate capital accumulation unless net profits fell below *b*, by making the costs of decelerating investment lower than the costs of underutilizing capacity.

Formally, the investment function for firm *i* is the following:

$$g_t = \frac{I_t}{K_t} = f(u_t) = F_{a,b}(u_t) \tag{7}$$

Where $F_{a,b}$ is the hysteresis operator that can take on value α or (α + β u_t) according to the rate of capacity utilization:

$$g_t = \begin{cases} \alpha + \beta u_t, & if \;\; u_t > a \\ \alpha, & if \;\; u_t < b \\ g_{t-1}, & if \;\; b < u_t < a \;\; and \;\; g_{t-1} = \alpha \\ g_{t-1} + \beta(u_t - u_{t-1}), & if \;\; b < u_t < a \;\; and \;\; g_{t-1} = \alpha + \beta u_{t-1} \end{cases} \tag{8}$$

Suppose for instance that a given firm produces at a rate of capacity utilization higher than *b* but lower than *a*, and invests an amount of fixed capital equal to $g_{t-1} = \alpha$. Suppose now that demand suddenly increases and the increase is expected to last for a long period: to the extent that the demand shock is sufficiently high to allow the firm pushing the rate of capacity utilization upwards and increasing net expected profits above *a*, the rate of capital accumulation will also *shift* upwards to ($\alpha + \beta\, u_{t+1}$) in order to adjust productive capacity at a higher level. If, however, a recession resulted in expected net profits falling back to the initial level, the rate of capital accumulation would certainly fall to ($\alpha + \beta\, u_{t+2}$) , with $u_{t+2} < u_{t+1}$, but it would not revert to α unless the expected rate of capacity utilization fell below b.

Hence, the rate of accumulation would be permanently higher with respect to the initial level, although the positive demand shock was only temporary and expectations were eventually correctly revised, since the investment decision made in the aftermath of the positive demand shock implied long-term sunk costs that cannot be recovered and that would be lost is the firm decided to revise downwards investment decisions. Furthermore The same applies if the firm produces at a rate of capacity utilization higher than *b* but lower than a, and invests an amount of fixed capital equal to $g_t = \alpha + \beta u_t$. If demand suddenly falls below *b*, the firms will decrease the rhythm of accumulation, and even though the rate of utilization were to go back to $u_{t+1} = u_t$, the firm would still be investing at a lower and constant rate, that is $g_{t+1} = \alpha$. In this case, the rate of accumulation would be permanently lower with respect to the initial level, since once capital has been dismissed, reaching the initial rythm of accumulation would require a higher expected demand.

At the macroeconomic level, as the economy is made of several firms with different sunk costs and different expectations, a given sequence of aggregate demand shocks will imply different and *discontinuous* reactions in terms of capital accumulation, which might cause hysteresis to occur.

3.2.4. Income distribution, employment and consumption decisions

Firms employ workers according to a standard Leontieff production function with complementary factors and scarce capital. Therefore, a given amount of output is associated with a given stock of capital and a given number of workers:

$$\begin{cases} Y = \min\{BK, AL\} = BK \\ L = \frac{B}{A}K \end{cases} \qquad (9)$$

B represents the inverse of the capital to output ratio (the “productivity of capital”), which is assumed to be constant and, for the sake of simplicity, equal to 1, while *A* represents the inverse of the labour to output ratio (“labour productivity”). Therefore, employment increases whenever the rate of capital accumulation exceeds the rate of growth of labour productivity, and it decreases whenever labour productivity grows faster than capital accumulation[18]:

$$\hat{L} = \frac{\dot{L}}{L} = \frac{\dot{B}}{B} - \frac{\dot{A}}{A} + \frac{\dot{K}}{K} = -\hat{A} + g_t \tag{10}$$

Labour productivity is a firm-specific variable: firms invest in labour saving and innovative technologies in order to develop inter- and intra-organizational capabilities and enhance the organization of labour resulting in a higher firm-specific productivity. The labour productivity function is the following one:

$$\begin{cases} A_{i,t} = A_{i,t-1}(1 + \hat{A}_{i,t}) \\ \hat{A}_{i,t} = \hat{A}_{i,t-1} + \varepsilon(\widehat{A^*}_{i,t} - \hat{A}_{i,t-1}) \\ \widehat{A^*}_{i,t} = g_{i,t} \end{cases} \tag{11}$$

Productivity at time *t*, $A_{i,t}$, is equal to productivity at time *t-1*, $A_{i,t-1}$, plus the rate of growth of labour productivity at time *t*, $\hat{A}_{i,t}$. The rate of growth of labour productivity at time t, on the other hand, is equal to the rate of growth of labour productivity at time t-1 $\hat{A}_{i,t-1}$, plus the difference between the *desired* rate of growth of labour productivity $\widehat{A^*}_{i,t}$, which is equal to the rate of capital accumulation $g_{i,t}$, and the actual rate of growth of labour productivity $\hat{A}_{i,t-1}$. According to the second and third equation in (11), firms aim to adapt the rate of growth of labour productivity to the rate of growth of capital, which is the rate of growth necessary to keep employment constant. The parameter ε reflects the ability of firm *i* to innovate and adapt labour productivity to capital accumulation: the more ε gets close to 1, the easier firms can adapt labour productivity to capital accumulation[19].

Once firms employ workers, they pay wages[20] according to the union's targeted wage rate, which is defined as a targeted share $\overline{w}$ of the *potential* output to labour ratio $\frac{Y^p}{L}$, and to the bargaining power of the union, η_t:

[18] For the sake of simplicity, the rate of population growth is equal to 0

[19] Although labor productivity is endogenous with respect to output, ε should not be interpreted as a Verdoorn's coefficient but rather as a firm specific capability to develop labor saving techniques. The rationale of the function is that firms aim to push the rate of growth of labor productivity up to (or above) the rate of capital accumulation in order to save on labor costs and accumulate more profits. From this point of view, the rationale behind the idea of a "desired rate of labor productivity" is not different from the rationale behind the idea of a "desired rate of capacity utilization": they both represent intermediate requirements to achieve a "desired rate of profit". Appendix 3.2 provides a sensitivity analysis on the value of epsilon.

[20] Since prices are constant and equal to 1, wages are expressed in real terms.

$$W = (\overline{w}\eta)\frac{Y^p}{L} \quad (12)$$

The bargaining power of unions, η_t, is itself an increasing function of the rate of employment (there is a "Phillips effect"), defined as the ratio of the employed persons to the active population, plus an exogenous component x_t which reflects institutional factors as well as the monopolistic structure of the market:.

$$\eta_t = (\Omega * \frac{L}{AP}) + x_t \quad (13)$$

For the sake of simplicity, $\Omega = 1$ and $x_t = 0$ in the baseline scenario, therefore the bargaining power of unions is simply equal to the rate of employment[21]. This will imply that when the employment rate approaches 100 %, the actual wage rate and the *desired* wage rate coincide. When, on the other hand, the employment rate is weaker, the actual wage rate will be consistently lower with respect to the targeted rate. Consequently, income distribution ultimately depends on the employment rate (the balance of power between capitalists and workers), that itself depends on the relative speed of capital accumulation with respect to labour productivity growth.

The residual, that is the difference between value added and wages, is distributed to capitalists, who take consumption and saving decisions according to their propensity to consume, c_K.

This model, according to the PKK literature and Kalecki's own works, assumes a propensity to consume out of wages equal to 1 and a propensity to consume out of profits

[21] Equations (12) and (13) state that although the union might target a given wage share, $\overline{w}$, she will only get a fraction of this target according to her bargaining power, which depends on the rate of employment and on the broader institutional and economic environment. The bargaining power of the union therefore is implicitly defined as the capacity of the union to bargain a wage bill that is consistent with the desired wage share. This assumption does not necessarily require rational expectations, since the union does not bargain an equilibrium real wage – she bargains a nominal wage bill, according to her expectations about future prices and to her *desired* wage share, and will obtain ex post only a fraction η of the *desired* wage share, which is not necessarily the *equilibrium* wage share.
Note that PKK models often assume that the wage rate is a share of actual, rather than *potential*, "labour productivity" (Hein, 2005). In these models, for instance, the rate of employment is a function of the rate of capacity utilization, while in this model employment at the firm level is determined by the rate of capital accumulation, not by the rate of capacity utilization. Nevertheless, it turns out that this micro model is perfectly consistent with the results of standard macro PKK models. For instance, since the firm-specific rate of capacity utilization determines the firm-specific rate of capital accumulation, at the macro level the aggregate wage rate is still a function of the aggregate rate of capacity utilization and, therefore, of actual labour productivity.

lower than 1, consistently with the statement that "workers spend what they earn and capitalists earn what they spend"[22] (Kaldor, 1955).

3.2.5. Dynamics of the Agent-Based model

The model is made of *n* firms producing consumption goods by means of capital and consumption goods, and *m* firms producing capital goods by means of capital goods only. Firms' threshold values are assumed to be exogenous[23].

The model starts with a positive endowment of productive capacity and intermediate consumption goods that will allow firms to reproduce the output destroyed during the production process plus a value added. More precisely, each firm is endowed with the same initial productive capacity according to the productive sector, and the amount of intermediate consumption goods is the amount necessary to start production at the initial rate of utilization set exogenously to 80 %[24]. Firms produce according to a rate of capacity utilization equal to 0.8, employ workers according to (9) and distribute wages according to (12). The difference between value added and wages is distributed to capitalists. As soon as wages and profits are distributed, and both workers and capitalists purchased consumption goods, firms decide how much to produce the following production period according to (6).

Investment and intermediate consumption decisions are taken simultaneously: when firms set the new rate of capacity utilization according to (6), they decide how many intermediate consumption goods to purchase and how many capital goods to invest consistently with that rate of capacity utilization. In particular, investment decisions are taken

[22] The sentence "workers spend what they earn and capitalists earn what they spend" is often attributed to Michal Kalecki. However, it has become famous thanks to Kaldor (1955) who used it in order to paraphrase Kalecki's thought. What this sentence means is that while workers need to earn in order to spend (and they are supposed to spend entirely their monetary wage in consumption goods), capitalists need to consume in order to get profits from production. For instance, if capitalists had a propensity to save out of profits equal to 1, the only source of monetary revenues for firms would be the quantity of money anticipated through wages, which is exactly equal to the costs of production. It follows that capitalists as a class need to consume or to invest in order to create an additional source of income different from anticipated wages, and the more they consume or invest the more they get profits.

[23] The threshold values are computed according to a uniform distribution. A well-known property of *genuine* hysteresis is statistical stability, i.e. the independence on the specific distribution function chosen for switching values (Piscitelli et al, 2000). In a model with endogenous input, the distribution function will affect the sensitivity of transient equilibria with respect to a given shock, but it will not remove hysteresis as long as the threshold values *a* and *b* do not coincide, that is as long as firms' investment function is still non-linear and discontinuous.

[24] 80% is a rate of capacity utilization that can be reasonably taken as a rate of utilization that could characterize an economy without inflationary or deflationary pressures. It is also a very common rate, as can be ascertained on http://www.tradingeconomics.com/country-list/capacity-utilization

according to (8), while intermediate consumption decisions are taken according to a linear function of expected production:

$$I.C_{t+1} = \bar{\gamma} u_{t+1} Y_{t+1}^{p} = \bar{\gamma} Y_{t+1} \tag{14}$$

Where I.C. stands for "intermediate consumption" and $\bar{\gamma}$ is a constant parameter representing the fraction of output needed for intermediate consumption[25].

As soon as investment and intermediate consumption decisions are taken, firms purchase capital and intermediate consumption goods and observe the variation of inventories in order to estimate their global demand.

The following production period will start by producing at the rate of capacity utilization set in (6), employing workers according to (9), paying wages according to (12) and restarting the whole process as described above.

3.3.Emergent properties and reaction to shocks

The baseline scenario reflects the main reference properties of the model as regards employment dynamics, income distribution, capacity utilization and capital accumulation. By simulating simulate macro- or micro- economic shocks it is possible therefore to observe how the economy reacts with respect to the baseline scenario behaviour, in particular as regards the inability of the system to absorb the shocks and regain the initial growth path[26].

In order to try to keep the model as close to reality as possible, the values of some parameters have been chosen according to empirical estimates and to macroeconomic empirical trends. Namely, the baseline's scenario tries to reproduce the rates of capacity utilization, capital accumulation and unemployment, as well as income distribution of the French economy during expansionary periods. [27]

[25] The specific value of $\bar{\gamma}$ assumed during the simulations of the model in section 3 is inspired by Storm and Naastepad (2015).
[26] All simulations have been implemented under Netlogo 5.1.0. The program is available from the authors upon request.
[27] Appendix 3.1 summarizes the values of the parameters.

As simple and modest as the model might be, it may help to shed light on the current situation in many European countries and in particular the one that have suffered losses in potential output mentioned in section 1.2.1.

3.3.1. The "paradox of costs" and the consequence of cuts in the real wage

According to the mainstream view (see for example Layard et al, 1991), the rate of unemployment is positively related to the wage rate; therefore, lowering the unit labour costs of firms is supposed to foster new hiring and boosting employment because of a supply-side stimulus to the economy. From an economic policy standpoint, this is the "internal devaluation" strategy that has been followed since 2009 in many southern European countries like Greece, Portugal, Spain or Italy.

The "paradox of costs" highlights on the contrary that, as wages are a significant part of income for most households, lowering real wages implies lowering aggregate demand and hence the incentives to invest (Rowthorn, 1981; Storm & Naastepad, 2012; Lavoie, 2014). As a consequence we should expect the opposite result to dominate: lower real wages should be associated with a lower rate of capacity utilization and a lower rate of capital accumulation.

The simulations implemented show that the "paradox of costs" holds – and therefore, why the internal devaluation strategies are a failure.

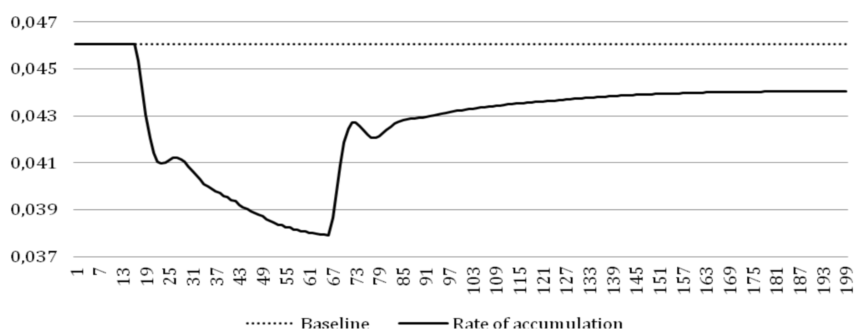


Figure 3.3: capital accumulation in the wake of a negative shock to unions' bargaining power

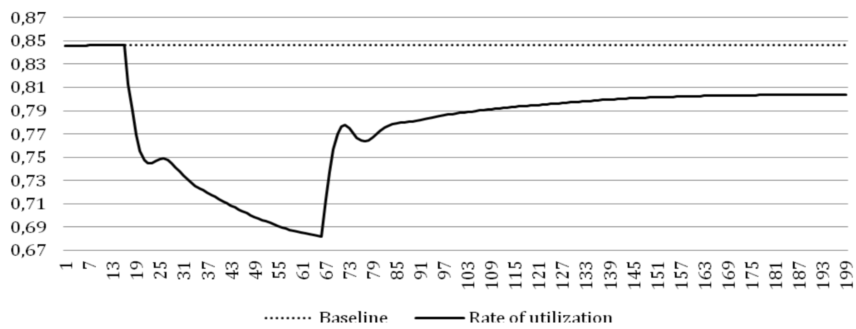


Figure 3.4: the rate of utilization in the wake of a negative shock to unions' bargaining power

Figure 3.5 the employment rate in the wake of a negative shock to unions' bargaining power

Figures 3.3 to 3.5 show the effect of a fall in the real wage to the rate of capacity utilization, to capital accumulation and to the employment rate.

At time t=15, a temporary negative shock to the exogenous component of the bargaining power of unions (x_t= -0.1) in both sectors triggers a fall in aggregate capacity utilization and, consequently, in the rate of capital accumulation. At time t=65 the shock is over but the economy does not regain the baseline's growth path: the rates of capacity utilization and capital accumulation, as well as the rate of employment, are permanently lower with respect to the baseline scenario, although the shock was only temporary.

The effect on productive capacity is therefore a permanent loss in the level and in the rate of growth, as shown in figure 3.6.

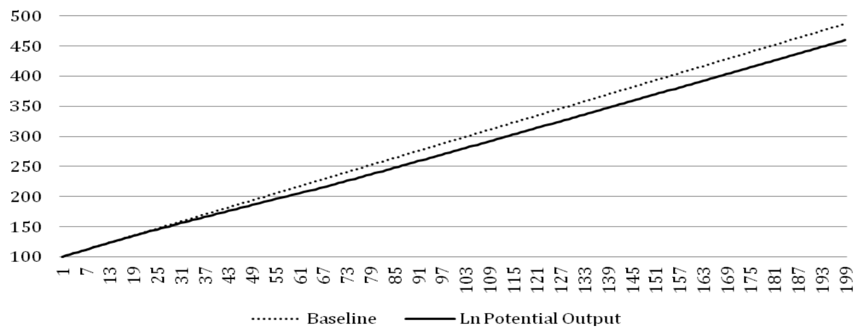


Figure 3.6: potential output in the wake of a negative shock to unions' bargaining power

As illustrated in figure 3.6, potential output falls below its baseline growth path and stabilizes at a lower level and a lower rate of growth – which is consistent with Ball's findings regarding Spain, Italy, Greece and Portugal.

The hysteresis effect on potential output growth can be explained through the effect of a temporary negative demand shock on firms' investment decisions. Since the propensity to consume out of wages is higher than the propensity to consume out of profits, a fall in the real wage implies a net fall in aggregate consumption and, thereby, in the rate of capacity utilization. Some firms will react to the negative demand shock by reducing the rhythm of accumulation and firing workers until productivity growth slows down and keeps up with the lower accumulation pace. As a consequence of the lower rate of employment, the real wage will fall even further until the negative shock is over and aggregate demand starts to increase again because of the increase in the real wage. However, some firms will not revert to the previous accumulation path despite the increase in aggregate demand as long as the rate of capacity utilization is too low to trespass the investment threshold a. These firms will only increase the rate of capacity utilization without increasing investments and employment. A negative temporary shock to the real wage therefore implies a shift to a new equilibrium characterised by a lower level of potential output and lower rates of capacity utilization, capital accumulation and employment.

3.3.2. The "paradox of thrift" and the Fisher effect

According to mainstream theory of growth, the rate of capital accumulation is positively related to the propensity to save either in the short- (Solow, 1956) or in the long run (Frankel, 1962; Romer, 1990).

In the PKK literature on growth and distribution (Rowthorn, 1981; Dutt, 1984; Lavoie, 1996, 2014) however, savings do not directly determine investments to the extent that the latter are independent on the propensity to save and only depend on the rate of capacity utilization, the “Keynesian Hypothesis” (Kaldor, 1955). In such a situation, increasing savings would not foster accumulation but would rather have the opposite result: as long as the aggregate propensity to consume falls, capital accumulation slows down because of the lower aggregate demand and the lower rate of capacity utilization. This negative effect of savings on capital accumulation has been defined as the *paradox of thrift*. The model, consistently with the PKK tradition, exhibits the *paradox of thrift* (see figures 3.7 to 3.9):

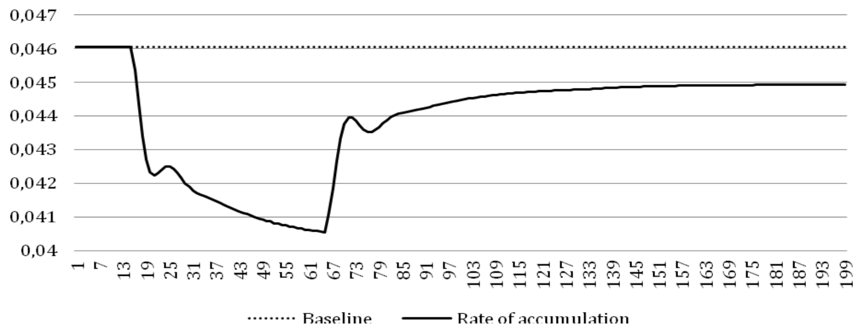


Figure 3.7: capital accumulation after a negative shock to capitalists’ propensity to consume

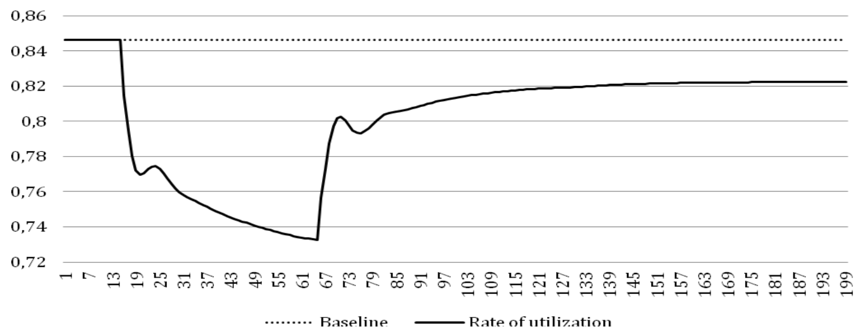


Figure 3.8: The rate of capacity utilization after a negative shock to capitalists’ propensity to consume

Figure 3.9: The employment rate after a negative shock to capitalists’ propensity to consume

Figures 3.7 to 3.9 show the effects on capacity utilization and capital accumulation of a negative shock to the propensity to consume out of profits. At time t=15, capitalists become more *virtuous* in the sense of Smith (1776): they increase the propensity to save out of profits by 12%. As a consequence of the lower aggregate consumption the rates of capacity utilization, capital accumulation and employment start to fall until capitalists keep on saving at the initial rate and the economy stabilizes at a new equilibrium characterized by a lower rate of utilization, a lower rate of capital accumulation and a lower rate of employment with respect to the initial growth path. The effects on potential output can be observed in figure 3.10.

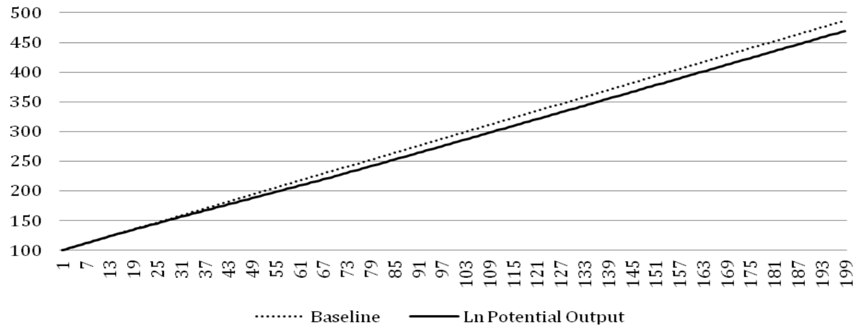


Figure 3.10 potential output after a negative shock to capitalists' propensity to consume

In Figure 3.10, potential output falls below its initial growth path and stabilizes at a lower level and a weaker rate of growth. Therefore, because of the discontinuity of investment decisions that do not respond linearly to aggregate demand shocks, a negative temporary shock to the propensity to consume out of profits implies a shift to a new equilibrium characterised by a lower potential output and lower rates of capacity utilization, capital accumulation and employment. Once again, the final equilibrium is history-dependent.

These results might be interpreted as an illustration of the Fisher (1933) effect: in recessions like the current one, firms and households are deleveraging. As a consequence, the saving propensity in the economy goes up, which depresses aggregate demand instead of stimulating it.[28]

[28] One has nevertheless to be cautious with this interpretation, as this economy is a real economy without any financial and banking sector.

3.3.3. Animal spirits and the propensity to invest

A third characteristic of PKK models is the positive relationship between the propensity to invest of firms and both the rates of capacity utilization and capital accumulation. Consistently with the Keynesian view regarding *animal spirits*, if entrepreneurs are caught by a wave of pessimism and decide to reduce autonomous investments, the rate of capacity utilization falls because of the lower effective demand, and capital accumulation consequently decelerates. The rates of capacity utilization and capital accumulation are particularly sensitive to *animal spirits*.

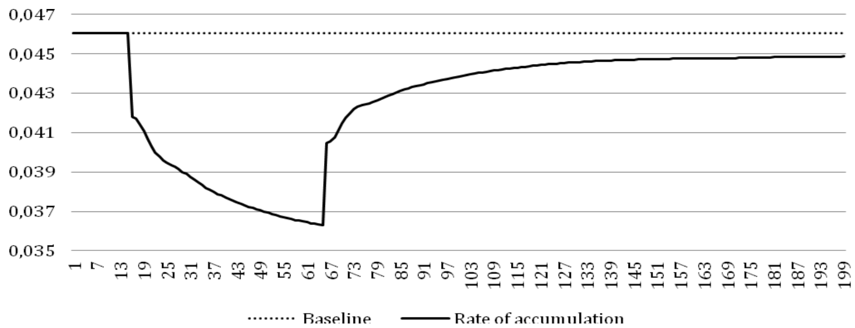


Figure 3.11: the rate of capital accumulation after of a fall in entrepreneurs' animal spirits

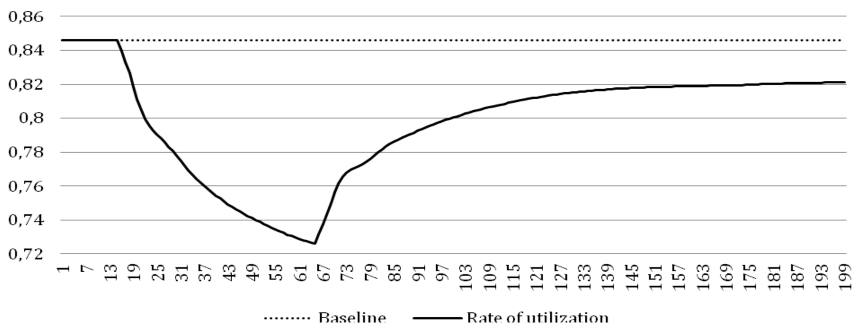


Figure 3.12: the rate of utilization after a fall in entrepreneurs' animal spirits.

Figure 3.13: the employment rate after a fall in entrepreneurs' animal spirits

Figures 3.11 to 3.13 show the effects on the rate of capacity utilization, the rate of capital accumulation and the employment rate in the wake of a fall in animal spirits. At time t=15 a negative temporary shock to *animal spirits* by 0.04 implies a fall in the rates of capacity utilization, capital accumulation and employment. When at time t=65 entrepreneurs keep on investing at the same secular pace, both the rates of capacity utilization and capital accumulation start to increase again but not sufficiently to regain the baseline growth path: the economy stabilizes at a new equilibrium characterised by a lower utilization, lower employment and lower accumulation of productive capacity with respect to the initial equilibrium. The effects on potential output can be observed in figure 3.14.

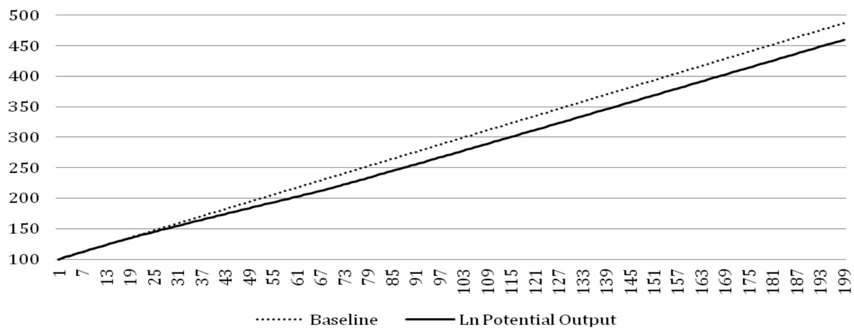


Figure 3.14: potential output in the wake of a fall in entrepreneurs' animal spirits

As is clear from figure 3.14, even if the negative shock was only temporary, the effects of the shock are long lasting, since the economy now stabilizes at a new equilibrium characterised by a lower potential output level and a weaker rate of accumulation with respect to the baselines's growth path. Furthermore, both the rate of utilization and the rate of employment are permanently lower.

This can once again shed light on the current situation of many European countries, where, as a consequence of the recession, animal spirits are depressed, which has had permanent consequences on potential output (see section 1.2.1).

3.4.Concluding remarks

In order to understand why potential output might suffer permanent losses in the aftermath of negative shocks, this PKK-ABM model of capital accumulation and growth assumed independent micro-decisions of heterogeneous firms generate history-dependent aggregate outcomes. As it is clear from the simulations implemented, the model is consistent with the “paradox of costs” and the “paradox of thrift”, and changes in animal spirits affect the long-run path of the economy permanently. As a consequence, this simple model can shed light on the loss of potential output in many European countries (Ball, 2014), which is the consequence of a combination of internal devaluation policies, the Fisher effect and depressed animal spirits.

This model contains several major innovations. Firstly, it relates three fields of knowledge that usually ignore the one another: PKK models of growth and income distribution, agent-based models and models of genuine hysteresis. Secondly, many papers on genuine hysteresis or on agent-based modelling have discussed the feedback effect of the output to the input without modelling it, while in this model the feedback effect is fully integrated – a novel feature that seems to be most desirable in economics in general and in this model in particular (as investment also influences aggregate demand). Thirdly, this simple theoretical framework allows showing that, under the simple (and realistic) assumption that heterogeneous firms adjust their rate of capital accumulation discontinuously, temporary shocks to the economy will have permanent effects on potential output: history matters and time is clearly historical time. As a consequence, there is no reason to expect potential output going back to its pre-crisis level in the aftermath of shocks.

The behaviour of potential output appears to be in line with the pattern observed by Ball (2014) in many European countries, that is, a permanent fall in potential output. The economic policy implication is most clear: if we want potential output to reach its pre-crisis level again, an exogenous economic policy intervention is needed. In this model, it means that authorities have to implement a shock in order to make sure that multiple firms will cross the α threshold by changing the animal spirits in a positive way (for example by announcing an expansionary fiscal policy), by increasing the capitalists’ propensity to consume (possibly by solving the deleveraging issue by writing off some debt) or by affecting income distribution in favour of wage-earners (by raising real wages, for example on the basis of a rise in the minimum wage; or by reinforcing unions and workers’ rights).

Nevertheless, the model has several limitations. All of them might constitute leads for future research. Firstly, like in the seminal paper by Dutt (1984), the economy is wage-led. As mentioned earlier, this can be justified by the empirical findings of Onaran and Galanis (2012). But Bhaduri and Marglin (1990) have shown that economies can also be profit-led when the depressive effect of a falling wage share on consumption can be more than compensated by the expansionary effect of the increasing profit share on investment. And as wage-led economies can become profit-led under some circumstances, and to cover the full range of possible situations, it would nevertheless be interesting to have both cases included in future models.

Secondly, the dynamics of prices are not taken into account. From that perspective, the bargaining/conflict part of the model needs to be enriched, for example along the lines suggested by Cassetti (2003) or Lavoie (2014). This is crucial if one wants to analyse how functional and personal income distribution are shaped in the economy and the permanent effects conflicts can have on the rates of growth, on capital utilization and on inflation. In order to reinforce this part of the model, one could also allow, in a more realistic fashion, to let the bargaining power of workers change with the rate of unemployment.

Thirdly, as population growth is left out of the model, the Verdoorn coefficient was supposed to be equal to unity at the equilibrium. Allowing the population to grow would allow introducing the consequences of capital accumulation on productivity consistently with Kaldor's and Verdoorn's empirical findings.

Fourthly, the way in which expectations and bounded rationality are can be complexified. For example, using "boundedly rational" expectations based on an artificial neural networks (Salle, 2015) is likely to generate richer and more complex dynamics and might prove interesting for future research.

Last but not least, like most PKK models, this one is a purely real one, in which both capitalists and workers are paid in real terms. In the absence of money, credit and banks, this economy is not a monetary economy of production. Even if firms are never constrained by the available amount of savings, they are not allowed to borrow in order to invest and produce either, while in actual economies money, credit and banking play a central role. The very presence of money and banking may allow for a dynamics of credit and private debt which can lead to endogenous cycles (Keen, 1995). It could then be possible to fully examine the consequence of the debt-deflation mechanisms *à la* Fisher in the presence of genuine hysteresis. This is an avenue for future research. Including credit in the model would be an important progress: even if the input is endogenous, the various shocks under consideration are still exogenous while in reality multiple shocks are endogenous by nature.

Next chapter will specifically focus on some of these evolutions, namely including a banking sector and a credit channel; including both real and nominal growth; introducing bargaining conflict in the model via a specific mark-up function; Moreover, the model in next chapter will remove the assumption of a unique input allowing each firm to have a specific rate market demand and a specific rate of capacity utilization.

Appendix 3.1: values of parameters

Description	Parameter	Value
Number of firms in consumption-goods sector	n	500
Number of firms in capital-goods sector	m	500
Active population	AP	9150
Initial capital stock of firms in consumption-goods sector	$K_{0,c}$	10
Initial capital stock of firms in capital-goods sector	$K_{0,k}$	1
Union's desired wage rate in consumption-goods sector	$\overline{w}_c$	0.2
Union's desired wage rate in capital-goods sector	$\overline{w}_k$	0.6
Accelerating investment threshold	a = f'(ζ)	Random ~ U(0.5, 0,9)
Decelerating investment threshold	b = f'(Γ)	Random ~ U(0.5, a)
Desired ratio of inventories over productive capacity	s^*	0.8
Exogenous investment parameter	α	0.005
Propensity to invest as a share of production	β	0.05
Share of intermediate consumption goods	$\bar{\gamma}$	0.67
Firms' ability to increase the output to labour ratio	ε	0.1
Potential output to capital ratio	B	1
Initial output to labour ratio	A_0	1
Sensitivity of unions' bargaining power to the employment rate	Ω	1
Propensity to consume out of wages	c_w	1
Propensity to consume out of profits	c_Π	0.25

Appendix 3.2: sensitivity analysis

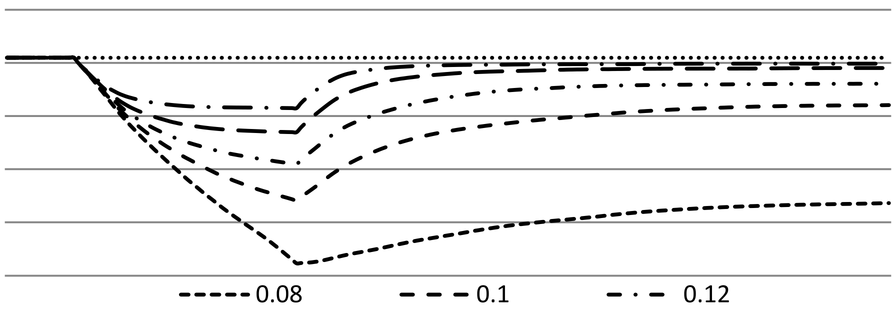


Figure 3.15: employment rate in the wake of a temporary negative shock to animal spirits by 0.05. Sensitivity analysis with respect to ε

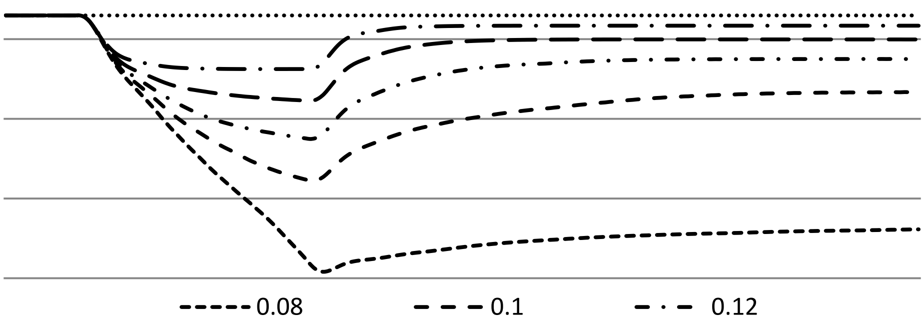


Figure 3.16: employment rate in the wake of a temporary negative shock to the bargaining power of unions by 0.08. Sensitivity analysis with respect to ε

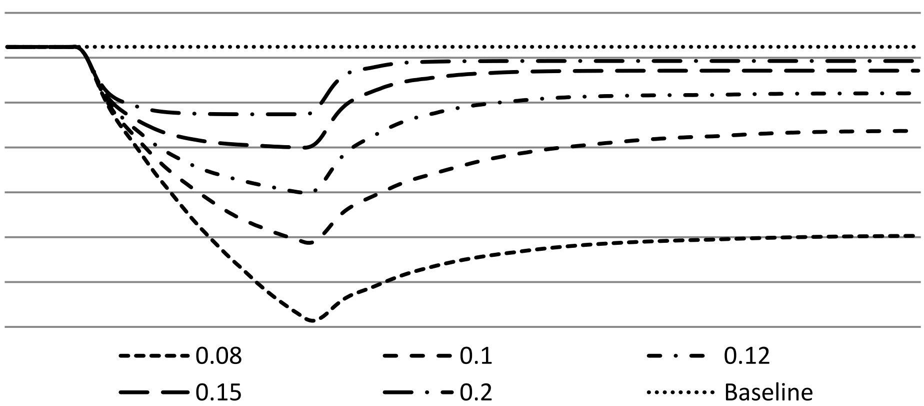


Figure 3.17: employment rate in the wake of a temporary negative shock to the propensity to consume out of profits by 0.15. Sensitivity analysis with respect to ε

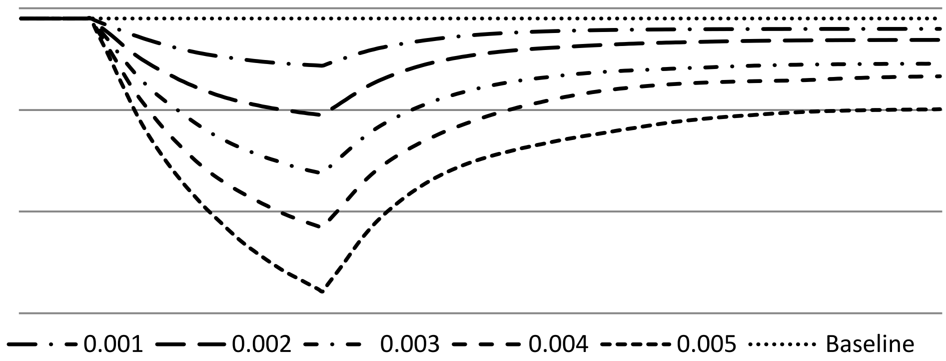


Figure 3.18: employment rate in the wake of a temporary negative shock to animal spirits. Sensitivity analysis with respect to different intensities of shock

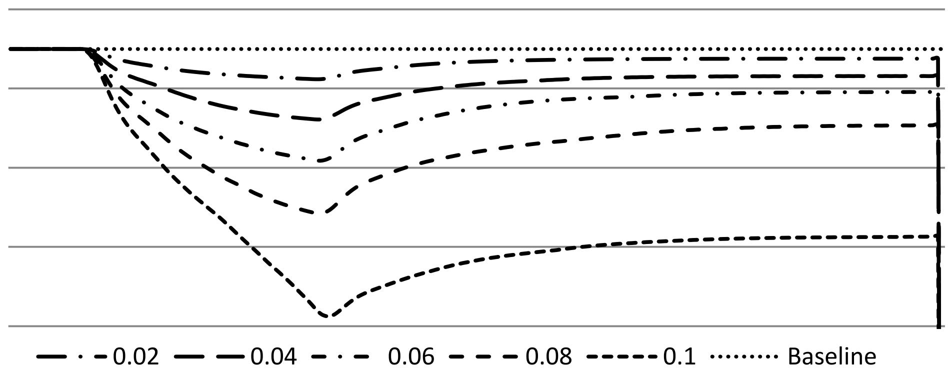


Figure 3.19: employment rate in the wake of a temporary negative shock to the bargaining power of unions. Sensitivity analysis with respect to different intensities of shock

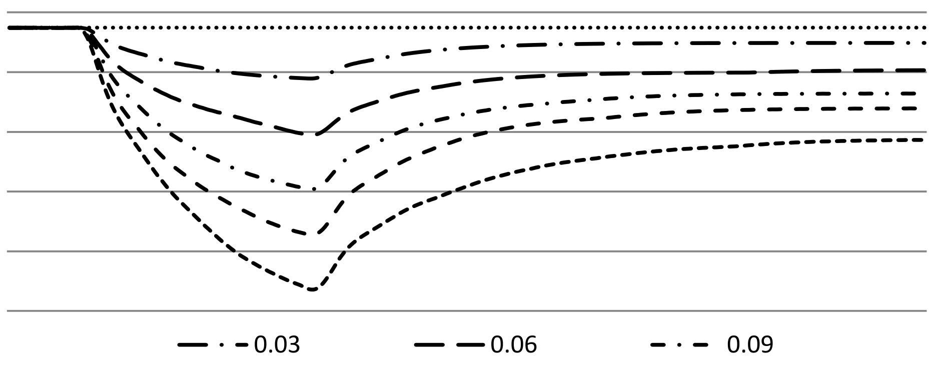


Figure 3.20: employment rate in the wake of a temporary negative shock to the propensity to consume out of profits. Sensitivity analysis with respect to different intensities of shock

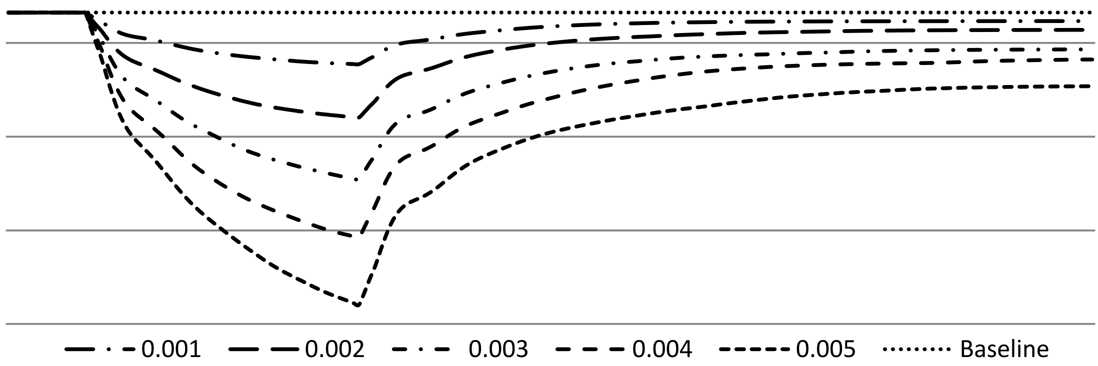


Figure 3.21: rate of capacity utilization in the wake of a temporary negative shock to animal spirits. Sensitivity analysis with respect to different intensities of shock

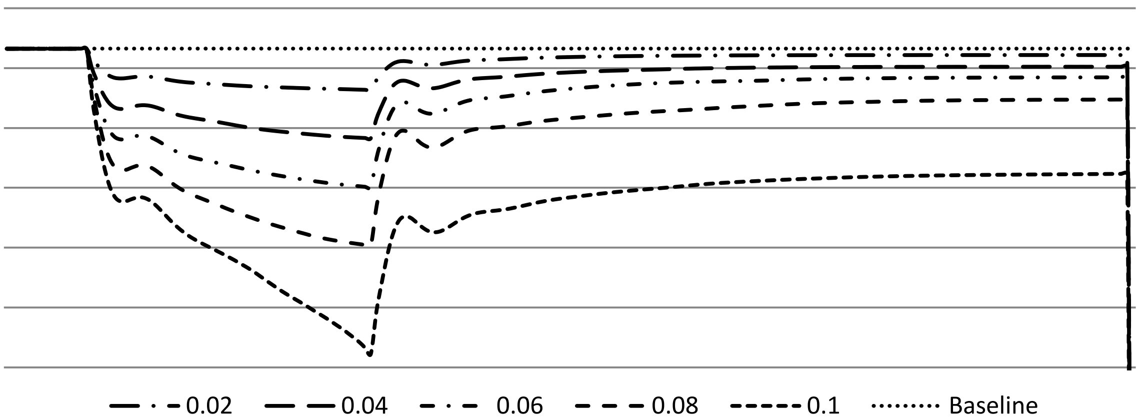


Figure 3.22 rate of capacity utilization in the wake of a temporary negative shock to the bargaining power of unions. Sensitivity analysis with respect to different intensities of shock

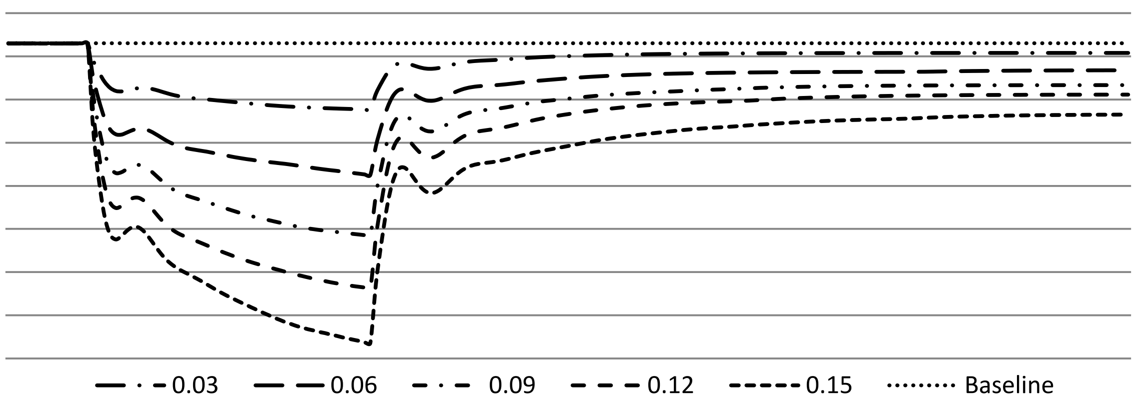


Figure 3.23: rate of capacity utilization in the wake of a temporary negative shock to the propensity to consume out of profits. Sensitivity analysis with respect to different intensities of shock

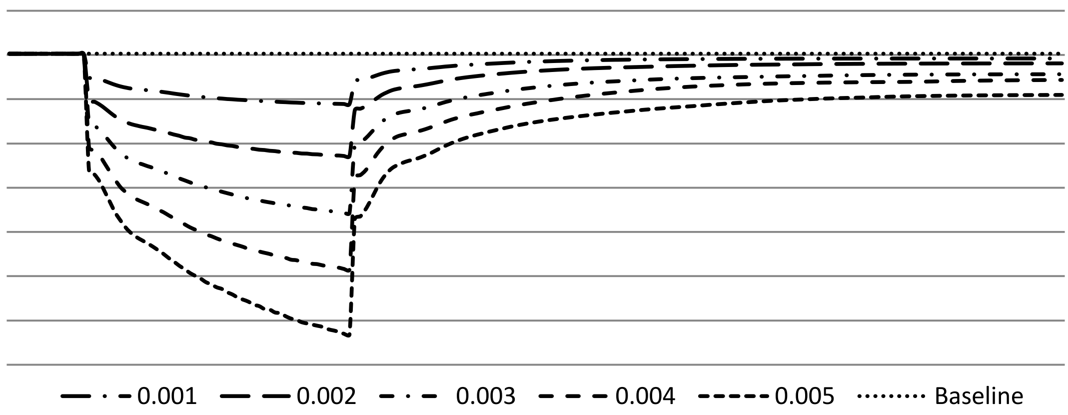


Figure 3.24: rate of capital accumulation in the wake of a temporary negative shock to animal spirits. Sensitivity analysis with respect to different intensities of shock

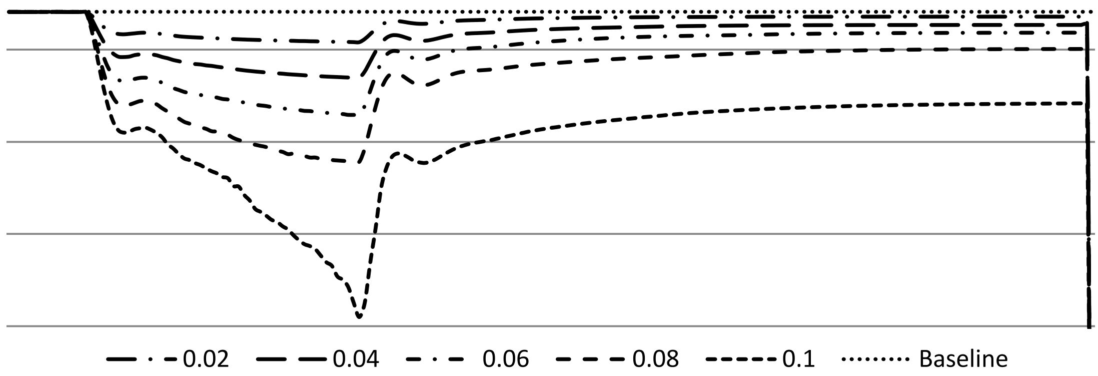


Figure 3.25: rate of capital accumulation in the wake of a temporary negative shock to the bargaining power of unions. Sensitivity analysis with respect to different intensities of shock

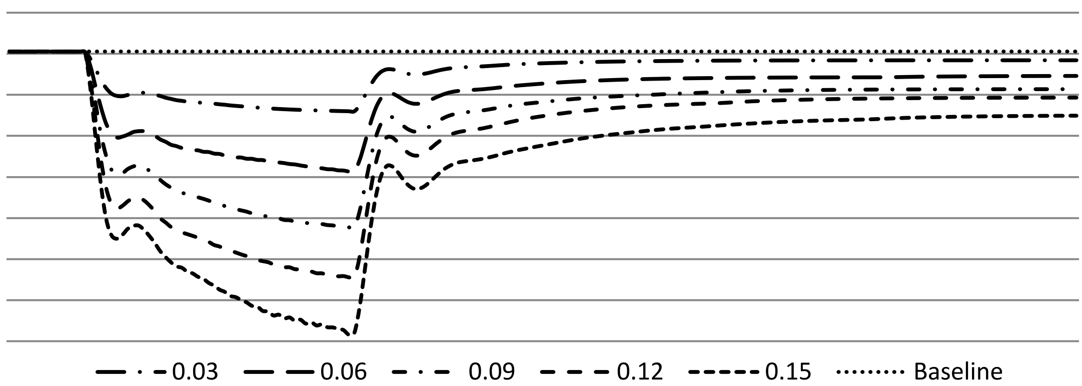


Figure 3.26: rate of capital accumulation in the wake of a temporary negative shock to the propensity to consume out of profits. Sensitivity analysis with respect to different intensities of shock

4. Coerced investments, growth/safety trade-off and the stabilizing role of demand policies. An Agent-based stock flow consistent model of endogenous business cycles and structural change

4.1. Introduction

Chapter 3 developed a simple Post-Keynesian/Kaleckian agent-based model with *genuine* hysteresis to show that transitory shocks to the propensity to save out of profits, to the real wage or to firms' *animal spirits* may not cancel out and imply a permanent change in the degree of capacity utilization, in the rate of unemployment and in the rate of capital accumulation. This happens when some firms standing in their *zone of inaction* permanently change their accumulation strategy in the wake of transitory shocks (see chapter 2). As a consequence, the model in chapter 3 supports the possibility to observe the economy fluctuating within a range of possible rates of capacity utilization, without triggering any endogenous mechanism of adjustment towards a predetermined *normal* degree. As a consequence, the paradoxes of costs and thrift hold in a long run horizon even when shocks are only transitory. Chapter 3 concludes by arguing that a recession followed by austerity measures will lead to a permanent loss of productive capacity. Furthermore, according to the property of *remanence*, exiting from the crises requires that positive demand shocks be more than proportionally higher with respect to the negative demand shocks that brought about the recession.

The model of chapter 3, however, did not include a fiscal or a monetary policy framework, consequently the conclusion was not supported by specific simulations. Moreover, it made other simplifying assumptions that chapter 4 relaxes in order to increase the level of complexity of the whole framework and extend the validity of the model. Namely, the model assumed for simplicity fixed prices and wages. Furthermore, it assumed a common sector-specific degree of capacity utilization for all firms, in order to focus on the discontinuity of capacity adjustments with respect to a common input, consistently with standard models of *genuine* hysteresis. As a consequence, the artificial economy of chapter 3 evolves on steady rates of capacity utilization, capital accumulation and unemployment, unless an exogenous transitory shock implies a disequilibrium process and then the convergence towards a new steady state. Thanks to this simplifying framework, however, it is possible to focus specifically on the properties of *genuine* hysteresis when feedback mechanisms running from output to input are explicitly taken into account. In particular, the model shows that hysteresis is contingent to two main assumptions: namely that labour productivity adjusts relatively slowly to capital accumulation and that the real wage is a function of unemployment. For instance, if labour productivity adjusted immediately to capital stock variations, a transitory shock would have no impact on the rate of unemployment and thereby on real wages. Consequently, we would observe the economy adjusting back to the initial steady state, without exhibiting hysteresis (see chapter 3 and Appendix 3.2). The same applies if real wages were independent from unemployment: in such a case, a transitory demand shock would have no permanent effect on the rates of utilization and capital accumulation, even though the rate of unemployment were permanently lower or higher. In other words, the *chain of causalities* that generate hysteresis starts from the discontinuity of investment decisions, which generates permanent variations of the rate of unemployment and, thereby, permanent variations in real wages. Consequently, the rate of capacity utilization and the rate of capital accumulation stabilize at a different steady rate. In chapter 4, these two assumptions - the relatively slow adjustment of productivity to capital accumulation and the pro-cyclical nature of real wages – will be retained. Nevertheless, the whole framework will be more complex. Namely, the model introduces a government and a monetary sector in order to take into account the effects of monetary and fiscal policies explicitly; it also assumes that wages and prices evolve endogenously, and that the rate of capacity utilization can be different for each firm, according to its price and its size. The model of chapter 4 will be mostly based on Dosi et al (2015), Assenza et al (2014) and Seppecher & Salle (2015). In these models, however, investment decisions are linear and depend on the discrepancy between actual and *normal* degree of capacity utilization, while the model of chapter 4 will assume a non linear and discontinuous investment function according to the *genuine* hysteresis framework developed in chapter 3.

In the recent macroeconomic mainstream literature based on the Real Business Cycles (RBC) or Dynamic Stochastic General Equilibrium (DSGE) approaches, which generally assume linear and continuous investment decisions, output fluctuations are explained through non-stationary and *ad hoc* technological shocks to potential output in a perfect competition framework characterized by full flexibility of prices and wages (Kydland & Prescott, 1982; King, Plosser & Rebelo, 1988; King & Rebelo, 2000) or in a imperfect competition framework characterized by friction in wages and price adjustments (Smets & Wouters, 2003; Justiniano & Primiceri, 2009; Vetlov et al, 2011). Despite the theoretical and methodological differences in these two approaches, we find some common patterns, namely that the output gap is equal to zero in the long run, despite transitory deviations, and consequently that permanently lower equilibrium rates of growth or output levels can only be explained through exogenous supply shocks, either stationary of non-stationary, affecting the level of capital rather than its degree of utilization. Consistently with this general framework, a growing stream of research has introduced some forms of non-linearity and discontinuity in capital stock adjustments at the micro-level in order to account for the empirically observed variability of aggregate investments during business cycles (Caballero & Pindyck, 1992; Bertola & Caballero, 1994; Abel & Eberly, 1999; Caballero & Engel, 1999; Veracierto, 2002; Thomas, 2002; Kahn & Thomas, 2008; Bachman et al, 2013). In particular, we can distinguish different approaches to discontinuity in investment decisions based on the (S,s) model. Caballero & Pindyck (1992), Bertola & Caballero (1994) and Abel & Eberly (1999) analyze the behaviour of firms with irreversible investments. In these models, firms can only increase their capital stock if it is lower than a certain *optimal*, or *desired* level, but they cannot scrap capital if they are caught with excess capacity except just letting capital depreciating at a fixed and constant rate (Abel & Eberly, 1999) rule out capital depreciation).

In particular, Abel & Eberly (1999) assumes the existence of a trigger value for the marginal efficiency of capital above which firms increase their capital stock in order to bring back the marginal efficiency to the *user cost* of capital, and below which firms are inactive. This trigger value, consistently with Dixit (1989), depends on uncertainty and on the unit cost of capital.

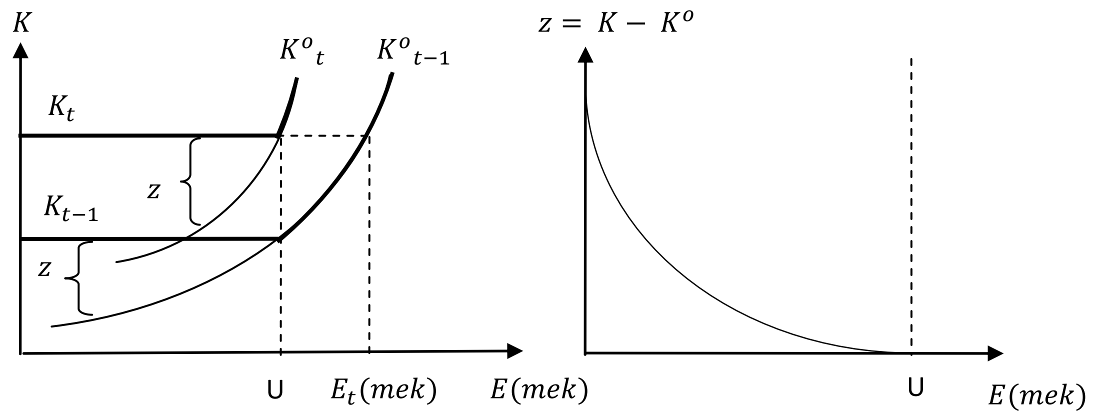


Figure 4.1: a own simplified reproduction of the Abel & Eberly (1999) model of irreversible investments.

Figure 1 is a simplifying reproduction of investment decisions in Abel & Eberly (1999). In the first graph, U represents the *user cost* of capital, the convex lines represent the *optimal* stock of capital and the bold functions represent the current stock of capital, which is equal to the *optimal* stock only when the expected marginal efficiency of capital is higher than the user cost. In the second graph, the convex lines represent the capital gap (excess capacity), which is equal to 0 only if the expected marginal efficiency of capital is above U. Indeed, if the expected marginal efficiency of capital increases above the user cost, the firm will invest until the marginal efficiency of capital goes back to the user cost. If, however, the marginal efficiency of capital falls below the user cost, the firm would virtually find convenient to scrap part of its capital stock, but since investments are irreversible it must bear the costs of excess capacity by keeping capital constant (capital is not allowed to depreciate in Abel & Eberly, 1999). This model implies irreversibility whenever the expected marginal efficiency of capital rises above U. In this case, the firm will increase its capital stock until the marginal efficiency of capital comes back to U. As a consequence, a transitory positive shock to the marginal efficiency of capital implies a permanent increase in the stock of capital. This model implies also cumulative non-neutrality, since a transitory negative shock to the marginal efficiency of capital would have no impact whatsoever on the capital stock, since the firm cannot scrap capital. Consequently, a transitory positive shock followed by a transitory negative shock would have a permanent effect. A transitory negative shock, however, would have no impact at all on capital stock, since investment is irreversible; therefore, transitory positive shocks have a permanent effect, while transitory negative shocks have no effect at all, neither transitory nor permanent.

Note that, in this model, investments do not exhibit lumpiness, since investment decisions do not imply non-convex adjustment costs. That is, firms can increase their productive capacity gradually without fixed costs. In order to take into account lumpiness and costly reversibility, the (S,s) literature has introduced the existence of non-convex (i.e. fixed) adjustment costs that create a form of symmetric discontinuity of capital stock adjustments. By assuming production losses (Caballero & Engel, 1999) or fixed labour costs (Thomas, 2002; Kahn & Thomas, 2008) related to productive capacity adjustments, either positive or negative, investment decisions exhibit a form of discontinuity and lumpiness. In these models, firms are supposed to maximize their value by taking into account the possibility to adjust the stock of capital to the *desired* level in order to raise profits but incurring in non-convex and convex costs, or not adjusting productive capacity accepting lower profits but lower costs as well. The existence of non-convex costs implies that the *capital* gap, which is the gap between current and *desired* capital, must be sufficiently high (in absolute terms) to make the marginal benefits higher than the fixed costs of adjusting productive capacity. For instance, if this gap is sufficiently low not to make the adjustment choice preferable to inaction, the firm will not adjust the capital stock and will keep a positive (in absolute terms) gap. Hence, the capital gap will always be lower (in absolute terms) than the minimum value necessary to imply a capital adjustment, which is a function of fixed costs. We can represent graphically the evolution of the *capital gap*:

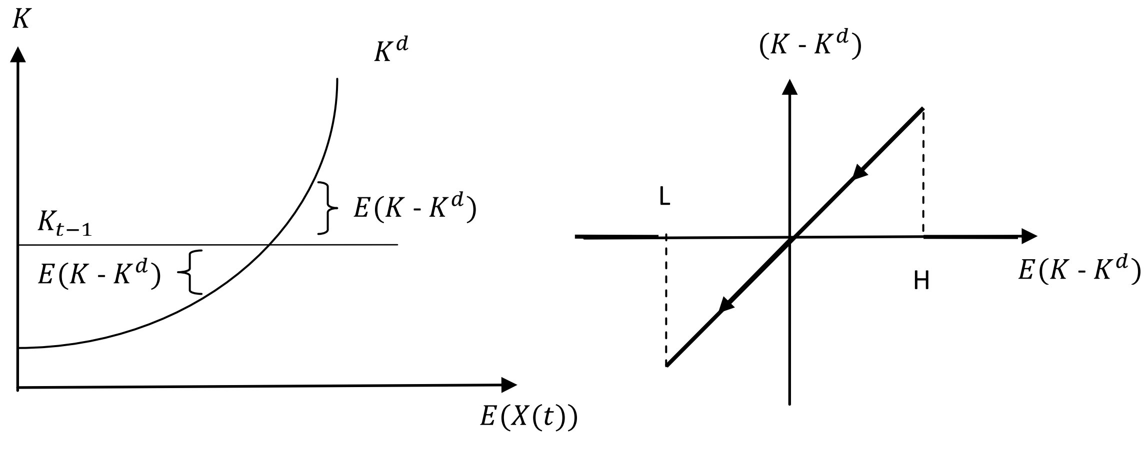


Figure 4.2: a own simplified reproduction of the Caballero & Engel (1999) model of lumpy and costly reversible investments.

Figure 2 is a simplifying reproduction of investment decisions according to Caballero & Engel (1999). In the left-hand graph, the convex line represents *desired* capital as a function of sectorial and idiosyncratic technological conditions, X(t), while the horizontal line represents the current capital stock. Shocks to X(t) imply different equilibria, or *desired* levels of capital stock and different expected gaps between *desired* and current capital. The firm will adjust the capital stock only if the *capital gap* is sufficiently higher (in absolute value) to make the fixed costs of adjustment lower than the expected marginal profits deriving from adjusting. To the extent that the firm maximizes its profits by fully adjusting capital stock to the *desired* level, there will be a corridor for the *capital gap* implying *inaction*. This corridor is delimited by two trigger values (H and L in the right-hand graph), which depend on fixed costs. Positive or negative gaps must therefore imply that the cost of adjusting capital stock in the current period is higher than the marginal profit. Nevertheless, if the firm decides not to adjust productive capacity and keep a positive or negative gap, in the next period the gap will be the same *net to capital depreciation*. Consequently, to the extent that the depreciation rate is positive, a positive *capital gap* will not be sustainable in the long run, since capital depreciation will reduce this gap down to zero. For the same reason, a negative *capital gap* cannot be sustainable as well, since capital depreciation will further increase this gap until the marginal profit of adjusting productive capacity offsets the fixed costs, thereby inducing the firm to adjust the current stock to the *desired* one. A positive or negative *capital gap* is therefore a short to medium run disequilibrium position that will adjust as soon as excess capacity depreciates or *overutilization* becomes unsustainable. Hence, the existence of adjustment costs creates a form of *friction* in investment decisions but not *hysteresis*, since the stock of capital will tend asymptotically to the *desired* level (and the *capital gap* to zero) because of endogenous forces driven by capital depreciation. The model can exhibit persistent fluctuations only if the process driving the *desired* level of capital is itself persistent. Caballero & Engel (1999), for instance, assume that *desired* capital evolves according to a random walk process, in line with the standard RBC literature. Non-convex adjustment costs, however, are not a necessary condition to have persistence; an accurate calibration of the model can generate persistent fluctuations even by assuming linear investment functions in otherwise standard RBC models (Veracierto, 2002; Thomas, 2002; Kahn & Thomas, 2008; Miao & Wang, 2014). Moreover, non-convex adjustment costs are not even a sufficient condition to have *hysteresis*: by assuming that desired capital follows a stationary and ergodic process, current capital would be stationary and ergodic as well, although exhibiting a small persistence depending on the weight of fixed costs relatively to capital stock depreciation.

These implications are the direct consequence of a set of assumptions concerning investment constraints. In particular, it is assumed that firms always target a *desired* capital stock and that the only impediment is the existence of fixed costs in productive capacity adjustments that do not allow adjusting systematically the current stock to the *desired* one. For instance, in the (S,s) literature, sunk costs have no impact on firms investment decisions in the long run, since capital depreciation can fully adjust excess capacity. Moreover, the decision to invest or not to invest does not impact on future market conditions, since these latter are assumed to be exogenous. In other words, there are no market or competition constraints in firms' investment decisions. Chapter 4 develops an agent-based model with discontinuous investment decisions that might account for persistent fluctuations and hysteresis. This model follows the (S,s) approach as regards the existence of two investment/disinvestment trigger values, but the trigger values depend on *routinized behavioural investment rules* rather than non-convex adjustment costs (Dosi et al, 2006). Moreover, it is assumed that firms do not invest/disinvest in order to reach a *normal* degree of capacity utilization that is supposed to minimize the costs of production, but they rather invest in order not to lose the pace with respect to competitors and not to risk exiting from the market. Sunk costs are interpreted here in a more dynamic sense with respect to the (S,s) literature, since they do not only affect the capital gap in the short run, but they affect investment decisions in a long run perspective. A stylized fact that ought to be explained, for instance, is not only that firms fail to exit from the market even though it would be *rational* to do it, but rather the fact that firms go on investing and accumulating excess capacity even though it would be rational to disinvest, downsize and, eventually, to exit:

"In industry after industry with excess capacity, managers fail to recognize that they themselves must downsize; instead, they leave the exit to others while they continue to invest. When all managers behave this way, exit is significantly delayed at substantial cost of real resources to society" (Jensen, 1993, p. 847)

The literature identified many aspects of the institutional, cultural and economic surround that might explain the incapacity of firms to exit form a declining market while simultaneously increasing further excess capacity. A first explanation relies on firms' accumulation strategies in relation to technological development. According to Jensen (1993), for instance, excess capacity can arise from capacity expanding-technological change. Moreover, to the extent that many competitors simultaneous rush to implement new technologies without taking into account the aggregate effect, productive capacity can grow faster than market demand. From this point of view, the globalization of markets made excess capacity a worldwide disease in many industries because of the larger international interdependencies. Crotty (2002) also insists on the effect of competition on investment decisions by highlighting the effect of globalization and the consequent "struggle to survive". In markets and industries characterized by global competition, firms must invest and expand productive capacity in order to exploit economies of scale and resist to competitors. In this framework, if a firm does not invest the risk is to exit from the market. Consequently, to the extent that investments are characterized by a large amount of sunk costs, firms are *coerced to invest* (Crotty, 1993) even though the rate of profit falls, because if they don't invest they risk losing competition and exiting from the market. According to Jensen (1993), it is a story of making major investments in order to "have a chair when the music stops". This effect is even stronger in large and fast growing companies:

"Exit problems appear to be particularly severe in companies that for long periods enjoyed rapid growth, commanding market positions and high cash flows and profits. In these situations, the culture of the organization and the mindset of managers seem to make it extremely difficult for adjustment to take place until long time after the problems have become severe, and in some cases unsolvable. In a fundamental sense, there is an asymmetry between the growth stage and the contraction stage over the life of a firm" (Jensen, 1993, p. 847)

Managers who invested large amounts of money in previous investments are reluctant to disinvest, even though the state of the economy worsens. This "tendency to continue an endeavor once an investment in money, effort, or time has been made" (Arkes & Blumer, 1985) is a common finding in behavioural experiments and it is often referred to as the *sunk costs effect*. There are many reasons explaining why people keep on investing in a certain project once time and money are invested in it, though actual results do not keep up with expectations. The desire not to appear wasteful, self-justification mechanisms or the attempt to take time and wait for new information before changing strategy can lead eventually to run a project far beyond its "life cycle" and *waste good money after bad* (Garland, 1990).

Assessing the long run implications of changes in economic environment is not easy, and the problem related to gathering and processing information becomes crucial. Firms often do not have good information about their own costs and even less about competitors' costs; as a consequence it is often difficult for managers to understand that they are the high-costs firm that should exit from the market (Jensen, 1993). Moreover, even though a firm is able to recognize its own vulnerability, it is not necessarily able to predict how long these changes will last and to what extent they require small adjustments or important restructuring (Schoenberger, 1994). Consequently, to the extent that firms must not merely decide between taking and not taking a certain decision, but also between doing it now and later on, it is rational to wait new information before deciding, especially if the decision implies large and sunk costs. Sunk costs and uncertainty can therefore explain this *wait and see* strategy (Dixit, 1992).

The lack of information, however, is not enough. Firms often do have the good information but fail to act on it, to mobilize it effectively. The fundamental variable to explain this failure to act appropriately is the way top managers see the firm and interpret the economic environment. According to Schoenberger (1994), in order to explain inappropriate corporate strategies we must focus on corporate strategists and the way their decisions are inextricably embedded in *power* and *identity* as social and historical products:

"Firms whose commitments are to aircraft, to mass production, to the network, etc, will have difficulty adapting to a world in which these commitments and identities are no longer valid. The people who run these firms need to realign these commitments, but, in order to do that, they must also rethink their own identities and how these are related to that of their firms. (...) In a sense, the real assets structure of the firm is shadowed by the managers' own asset structure which involves these powers of strategic conceptualization and valuation. Both sets of assets must be defended, although this task may, in particular historical moments, become deeply contradictory." (Schoenberger, 1994, p. 446)

According to Schoenberger (1994), inappropriate decisions are not the consequence of a lack of information, but the consequence of managers' defence of their own asset structures and their own power to define and create identities that can be threatened when important decisions for the firm are at stake, namely the decision to fundamentally restructuring the firm or exiting from a market. The agent-principal framework, in which managers (agents) do not own capital but have the power to take decision that contrast with shareholders' (the principal) interests, can offer an interesting insights over managers' resilience to take decisions that imply large restructuring or exit. Crotty (1993) and Clark & Wrigley (1997) formalize the agent-principal relationship in the growth-safety trade-off. Managers need, on one hand, to guarantee a satisfactory flow of dividends to shareholders in order not to lose legitimacy and control; and, on the other hand, they seek for growth and expansion in order to ensure the survival of the firm, which guarantees power and income to the management. In this framework, maximizing shareholders' profits is not an objective but rather a constraint in management desired to expand and accumulate. Closing the plant or exiting from the market is the ultimate strategy to pursue after several alternatives have been implemented and failed. Shutting plants or liquidating the firm can for instance imply a fundamental restructuring of managerial competences and roles, while firm's expansion can on the contrary open careers and offer more opportunities for promotion, thereby increase the power of managers in the firm. Consequently, managers tend to avoid exit decisions as long as they have sufficient cash to finance money losing investments, by rising what Jensen (1993) defines the agency costs of free cash flow.

Chapter 4 develops a theoretical model that takes into account the role of sunk costs, uncertainty and managerial discretion in firm's investment decisions. It is assumed that firms investment decisions during growth and declining cycles are fundamentally asymmetric (Jensen, 1993), and that firms are "coerced to invest" (Crotty, 1993, 2002), even though profits are falling, for different reasons including globalized competition, managerial discretion and sunk costs. The decision to liquidate plants and exiting the market is the ultimate decision that becomes unavoidable when firm's cash flow is insufficient to guarantee dividends and growth, it is not a simple mechanism for adjusting productive capacity to a cost minimizing *desired* level as in standard (S,s) models. Moreover, the model departs from the standard assumptions of the (S,s) literature according to which firms are rational profit maximizers constrained only by non-convex adjustment costs. Firms are bounded rational agents, constrained by aggregate demand and imperfect competition rules, which take decisions according to simple heuristics and routinized procedures, consistently with the Agent-based Computational (ACE) approach (Fagiolo & Roventini, 2012). In this framework, firms' investment decisions exhibit non linearity and discontinuity at the micro level and the aggregation of such non-linear and discontinuous investment functions implies endogenous persistent fluctuations and structural changes, a result that cannot be found in standard (S,s) models without assuming *ad hoc* non-stationary technological shocks. By introducing different monetary and fiscal regimes, it can be shown that countercyclical demand policies play a crucial role in stabilizing the economy and avoid long lasting recessions.

4.2.The model

4.2.1. Structure and timing of events

This model aims at reproducing an artificial economy in which heterogeneous agents belonging to different sectors (firms, households, banks, government) interact according to simple behavioural rules or procedures (Simon, 1972), by repeatedly changing the structure of the economy (Fagiolo & Roventini, 2012). Although behavioural rules do not need to satisfy general equilibrium constraints, aggregate results do satisfy stock-flow consistent requirements (Godley & Lavoie, 1997). For instance, the model ensures that individual- and sector-specific balance sheets, as well as the aggregate balance sheet, are always in balance according to the accounting principle of quadruple entry. The transaction and stocks matrices of the model are provided in appendix 4.2.

The timing of the events is the following:

1- Defaulted firms are replaced by new entrants

2- Consumption goods firms make production and investment plans. They ask capital goods firms for estimates and, after computing total costs (investment and wages) and internal sources of financing, they ask banks for loans and send to capital goods firms their orders by paying in advance.

3- Both consumption and capital goods firms employ workers, pay wages and start the production process. Unemployed labour force can receive a basic income by the Government according to the specific fiscal regime. The Government pays back the interests on issued bonds to the central bank and finances its own expenditure by taxing dividends made by capitalists and by issuing new bonds, which are purchased by the central bank.

4- Workers, unemployed and capitalists go shopping. Capital goods are delivered to consumption good firms. Consumption goods firms update their capital stock.

5- Consumption goods firms pay back their loans, pay interests and compute their profit. Profit is partially retained and partially distributed as dividends. Those firms that are not able to pay back their loans go defaulted. Capital goods firms compute their profit and distribute it entirely as dividends.

6- The commercial bank, after receiving interest payments by consumption good firms, pays interests on advances to the central bank and computes its profit. Since consumption good firms might default on loans, profits are partially retained in order to cover future potential losses and the rest is distributed as dividends. If the amount of reserves is not sufficient to cover legal thresholds, the commercial bank asks for advances to the central bank.

7- The central bank, after receiving interests on advances and interests on bonds (see point 3) computes its profit and distributes it entirely to the Government.

A graphical representation of the structure of the model is provided in appendices 4.3 and 4.4.

4.2.2. Capital goods firms

Following Dosi et al (2015), this model assumles that the capital goods sector produces by means of labour only according to the specific demand coming from consumption goods firms, which pay the whole price in advance. It also assumes that each consumption good firm purchases capital goods from a limited number of suppliers and splits its demand among them. Consequently, capital good firms do not need to ask for loans and do not need to accumulate stocks: supply perfectly adapts to demand and variable costs (wages) are perfectly covered. For instance, capital good firms fix their price according to a simple mark-up rule:

$$p^K{}_t = \frac{w^K{}_t * N^K{}_t}{Y^k{}_t} * (1 + m^K{}_t) \tag{1}$$

Where $w^K{}_t$ is the wage bill paid, $N^K{}_t$ is the number of workers employed, $Y^k{}_t$ is the quantity produced and $m^K{}_t$ is the mark-up[29]. By assumption, capital good firms produce a standard commodity without performing any R&D activity[30]. Capital good firms produce the quantity of goods demanded by consumption goods firms according to a linear function of production:

$$Y^K{}_t = I^C{}_t = lp^K * N^K{}_t \tag{2}$$

Where $I^C{}_t$ is the investment demand of consumption good firms and lp^K is labor productivity. Capital productivity grows uniformly across capital goods firms according to a sector-specific learning-by-doing dynamic:

$$lp_{j,t} = lp_{j,t-1} * ((Y^K{}_t - Y^K{}_{t-1}) / Y^K{}_{t-1}) \tag{3}$$

Profits for capital good firms are equal to:

$$\Pi^K{}_t = (p^K{}_t * Y^K{}_t) - (w^K{}_t * N^K{}_t) \tag{4}$$

[29] Following again Dosi et al (2015), the model assumes that the mark-up is constant for all capital goods firms.

[30] The capital goods sector, in this model, is extremely simplified because the focus in on consumption goods firms dynamics. Since innovation dynamics are beyond the scope of this model, following Assenza et al (2014) there is a standard capital good with no R&D activity performed by capital goods firms. An evolution of this model might take into account more complex and realistic dynamics including the existence of different vintages of capital goods with different performances and different labor requirements (Dosi et al, 2013, 2015).

4.2.3. Consumption goods firms

4.2.3.1. Production and productivity

Consumption good firms produce a homogenous non-perishable good using both capital and labour. Since they move in a radically uncertain environment (Keynes, 1921), in order to minimize the quantity of unsold commodities they try to predict their future demand by means of simple rules and heuristics, consistently with a "bounded rationality" framework (Simon, 1972). Since they don't know exactly their demand function, they accumulate positive stores in order to avoid out-of-stocks and monitoring their market demand: if stores increase over time, firms will interpret this increase as a falling demand; if stores decrease over time, firms will interpret this fall as an increasing demand. Therefore, the model assumes that firms target a "desired" level of stores computed as a fixed percentage of expected sales: if stores are lower than desired, firms will increase production, if stores are higher than desired, firms will lower production (Dosi et al, 2015; Seppecher & Salle, 2015). However, firms can still end up out-of-stocks if demand is higher than expected, and observe "queues" out of their shops (Assenza et al, 2014). In this case, they will revise upwards their production plans in order to avoid future out-of-stocks. The production function of firms is the following:

$$Y_{i,t} = Q_{i,t-1} + {Q^u}_{i,t-1} + ((s^* * Sales_{i,t-1}) - S_{i,t-1}) \quad (5)$$

Where $Q_{i,t-1}$ is the quantity of commodities sold, $Q_{i,t-1}$ the quantity of commodities that might have been sold in case of out-of-stock, s^* the desired ratio of stores over expected production and $S_{i,t-1}$ the quantity of commodities stored.
Sales depend on customers' preferences. Customers purchase consumption goods, by visiting a limited number of firms, according to a negative function of price and a positive function of firm's size: big firms will have a higher absolute demand with respect to small firms, while cheaper firms will have a higher absolute demand with respect to expensive firms.

$$Sales_{i,t} = \left(\frac{K_{i,t}}{\bar{K}_t}\right) * \left(\frac{\bar{p}_t}{p_{i,t}}\right) \quad (6)$$

$K_{i,t}$ is the stock of capital, $\bar{K}_t$ the average stock of capital of consumption goods firms, $p_{i,t}$ is the price and $\bar{p}_t$ the average price of consumption goods firms. Although consumption goods firms produce using a standard capital good, their productivity follows a firm-specific learning-by-doing dynamic (Arrow, 1962): the more a firm accumulates capital, the higher its labour productivity[31]. Labour productivity growth depends therefore on capital accumulation and on a parameter ε, which represents the capability of firms to develop labor-saving production techniques:

$$\dot{lp}_t = (\dot{lp}_{t-1} * (1 - \varepsilon)) + (\varepsilon * \dot{K}_t) \quad (7)$$

4.2.3.2. Wages, mark-up and pricing

Wages are set according to the bargaining power of unions on one hand, and the relative competitiveness of firms on the other: well performing firms pay higher wages with respect to poorly performing firms. On aggregate wages increase more rapidly when the rate of unemployment is low and the cost of living is higher (Phillips, 1958), while at the firm-specific level, wages are positively related to labor productivity growth and to relative price[32]:

$$w_{i,t} = w_{i,t-1} * (1 + (\delta_1 * \frac{\bar{p}_t}{p_{i,t}}) + (\delta_2 * \dot{lp}_{i,t-1}) + (\delta_3 * \dot{\bar{p}}_{t-1}) - (\delta_4 * u_{t-1})) \quad (8)$$

Where $\dot{\bar{p}}_{t-1}$ is the rate of price inflation of consumption goods and u_{t-1} is the rate of unemployment. Prices, on the other hand, are set according to the same mark-up rule of capital goods firms:

$$p_{i,t} = \frac{N_{i,t} * w_{i,t}}{Y_{i,t}} * (1 + m_{i,t}) \quad (9)$$

Consistently with the Kaleckian theory of pricing, the mark-up reflects the monopolistic power of the firm. Firms set their mark-up by looking at the differences between their own price and the industry price: if the price is lower than the industry price, the firm will increase the mark-up, if the price is higher than the industry price, the firm lowers the mark-up (Basile & Salvadori, 1984). The mark-up, however, is also supposed to reflect income distribution dynamics and capital financing ability (Lavoie, 2001): a higher rate of unemployment will imply a lower bargaining power of workers, thereby an increase in the mark-up of firms; moreover, a higher real interest rate will imply a higher burden of debt, thereby an increase in the mark-up. The mark-up equation is the following:

$$m_{i,t} = (\beta_1 * (\frac{\bar{p}_t}{p_{i,t}})) + (\beta_2 * u_{t-1}) + (\beta_3 * (int^e{}_t - \dot{p}_{i,t-1})) \quad (10)$$

---

[31] This simplifying assumption is related to the previous assumption according to which capital good firms do not perform R&D activity.
[32] Wages in the capital-goods sector are set according to this same function.

Where $int^{e}{}_{t}$ is the rate of interest effectively paid to the commercial bank and $\dot{p}_{i,t-1}$ is the rate of growth of firm's price.

4.2.3.3. Investment decisions

In order to substitute the depreciated capital stock and to increase productive capacity, firms invest in new capital goods. While the substitution of depreciated capital stock depends on the rate of capital depreciation, γ_2, the decision to increase productive capacity depends on *animal spirits* γ_1, on the long run rate of capacity utilization and on the long run rate of profit (See Setterfield & Budd, 2010):

$$I_{i,t} = K_{i,t} * (\gamma_{1,i,t} + ((\gamma_3 + \gamma_{4,i,t}) * lrut_{i,t}) + (\gamma_5 * lr\pi_{i,t})) \tag{11}$$

As regards *animal spirits*, consistently with De Grauwe (2011) the model assumes two types of firms, the optimistic and the pessimistic ones. Furthermore, following Seppecher & Salle (2015), it assumes that the probability of being optimistic or pessimistic depends on effective demand, proxied by the rate of capacity utilization. In particular, firms have a certain probability ψ of being optimistic when the rate of capacity utilization is above its estimated long run trend and a probability ψ of being pessimistic when capacity utilization is below its estimated long run trend. When optimistic, $\gamma_1 = 0.01$, when pessimistic $\gamma_1 = 0$:

$$lrut_t = (\rho * lrut_{t-1}) + ((1 - \rho) * ut_t) \tag{12}$$

$$\begin{cases} P(\gamma_1 = 0.01 | \, ut_t \geq \, lrut_t \,) = \, \psi \\ P(\gamma_1 = 0 \mid ut_t \geq \, lrut_t) = (1 - \psi) \\ P(\gamma_1 = 0 \mid ut_t < \, lrut_t) = \, \psi \\ P(\gamma_1 = 0.01 \mid ut_t < \, lrut_t) = (1 - \psi) \end{cases} \tag{13}$$

Note that *animal spirits* here are thought as a short run and cyclical component depending on demand fluctuations around a long run trend, they do not refer to a long run horizon as in Setterfield & Budd (2010). Long run expectations are reflected in the growth/safety trade-off of managers (Crotty & Goldstein, 1992; Crotty, 1993). In this model, managers invest according to their degree of confidence in the state of the economy, which is relatively stable and which affects their relative preference for safety or growth. In particular, it depends on their perception about sunk costs (Arkes & Blumer, 1985; Garland, 1990), on their degree of uncertainty and the consequent preference for time (Dixit, 1992) as well as on their perception about the intensity of technological competition (Crotty, 1993, 2002). Therefore, this model assumes that the degree of confidence changes discontinuously when expectations are sufficiently disappointed to imply a shift from a "safety-based" to a "growth-based" mode of accumulation or the opposite way round, according to the degree of long run capacity utilization relatively to the trigger values a and b:

$$\begin{cases} \gamma_{4,t} = 0.015 & if \quad lrut_t > a \\ \gamma_{4,t} = 0 & if \quad lrut_t < b \\ \gamma_{4,t} = \gamma_{4,t-1} & if \; b < lrut_t < a \end{cases} \tag{14}$$

We can represent the relationship between the *long run* rate of capacity utilization and capital accumulation in figure 3:

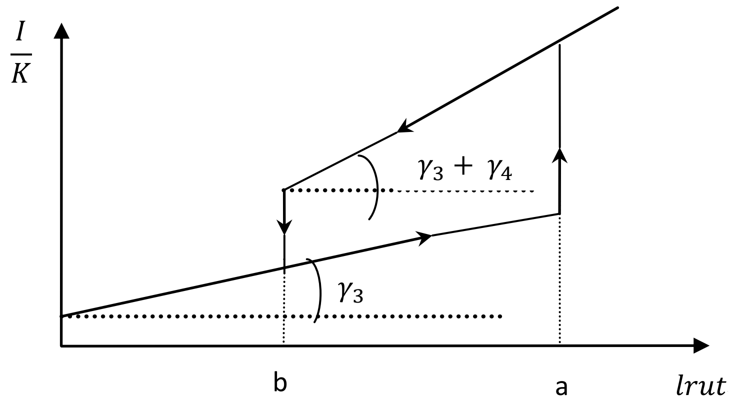


Figure 4.3: capital accumulation as a non-linear function of the long run rate of capacity utilization

When the long run rate of capacity utilization increases above a, the management shifts to an *optimistic* "growth-based" mode of accumulation that implies, *ceteris paribus*, larger investments. In order to shift to a pessimistic "safety-based" mode of accumulation the degree of utilization must fall sufficiently to trespass the lower trigger b. In this case, for instance, the managers will perceive a large threat to the stability and survival of the firm and will consequently revise downwards their production plans. Therefore, there is a corridor, in between a and b, which implies the stability of managers' growth-safety preferences.

4.2.3.4. Profits, retained earnings and loans

Consumption goods firms produce final goods by means of capital and labor: those commodities that are sold turn into liquidity, while unsold commodities are stored at their current market price. After selling commodities to the market, firms pay back their loans, depreciate their capital stock, evaluate their non-liquid assets (stores) and compute their accounting profits according to the following equation:

$$\Pi_{i,t} = (Sales_{i,t} * p_t) - (w_{i,t} * N_{i,t}) - int_t - (K^v{}_{i,t} * \gamma_2) + ((S_{i,t} * p_{i,t}) - (S_{t-1} * p_{t-1})) \quad (15)$$

Where $K^v{}_{i,t}$ represents the accounting value of the stock of capital. Since stored commodities and capital goods are not liquid assets, firms compute their cash flows according to the following equation:

$$\Pi^{cf}{}_{i,t} = Sales_{i,t} - (w_{i,t} * N_{i,t}) - int_t \quad (16)$$

Part of the cash flows are retained in order to finance future investments, the rest is distributed to capitalists as dividends. The retaining policy of the firm depends on its liabilities and its capacity to distribute dividends. For instance, firms' management faces a constant trade-off between growth and safety (Crotty, 1993): investment implies growth and profits but also, implicitly, a promise to shareholders to distribute higher dividends and a commitment to pay back interests over debt. Safety with respect to both shareholders and creditors implies that retained earnings are a function of both the debt-to-equity ratio and the dividends-to-equity ratio: the higher the debt-to-equity and the dividends-to-equity ratios, the higher the share of retained profits:

$$\lambda_{i,t} = (\mu_1 + (\mu_{2,t} * \frac{LB_{i,t}}{NK_{i,t-1}}) + (\mu_3 * (\frac{\Pi^d{}_{i,t-1}}{NK_{i,t-1}}))) \quad (17)$$

$LB_{i,t}$ is the value of firm's liabilities, $NK_{i,t-1}$ is the net capital of the firm and $\Pi^d{}_{i,t-1}$ is the amount of dividends distributed. Note that this assumption is almost equivalent to assuming a targeted debt-to-equity ratio (Riccetti et al, 2013). Nevertheless, instead of targeting a fixed rate by reducing/increasing investments accordingly, firms are concerned with stabilizing their leverage ratio by means of retained earnings and investments (through the effects of debt on profits) given the state of confidence of managers about the growth/safety trade-off. Retained cash flows are equal to:

$$RE^{cf}{}_{i,t} = \max(\lambda_{i,t} * \Pi^{cf}{}_{i,t}, 0) \quad (18)$$

While dividends will be equal to:

$$\Pi^d{}_{i,t} = \Pi^{cf}{}_{i,t} - RE^{cf}{}_{i,t} \quad (19)$$

Consumption goods firms can finance investments and production by using retained earnings and, if not sufficient, by asking for a loan to the commercial bank:

$$L_{i,t} = (I_{i,t} * {p^k}_{i,t}) + (L_{i,t} * w_{i,t}) - Dep_{i,t-1} \quad (20)$$

$Dep_{i,t-1}$is the amount of liquidity of the firm. Since loans are paid back over $n=5$ time periods[33], the liabilities structure of the firm is equal to the sum of loans that are not yet paid back to the commercial bank.

4.2.4. Households

Consistently with the Post-Keynesian/Kaleckian literature, households are divided in two main categories: workers - those who "spend what they earn" - and capitalists - those who "earn what they spend" (Kaldor, 1955). The sources of income for workers are wages paid by consumption and capital good firms, and the basic income provided by the government to the unemployed. The source of income for capitalists is the amount of dividends paid by consumption and capital good firms and by the commercial bank. By departing from the standard Kaleckian assumption of zero savings for workers, the model assumes instead a positive (but lower than 1) propensity to consume out of wages as well as a positive (but lower than 1) propensity to consume out of savings, consistently with most AB models (Riccetti et al, 2013; Assenza et al, 2014; Seppecher & Salle, 2015). The same applies for capitalists, although the propensities to consume out of income and out of savings are lower with respect to workers. Furthermore, following again De Grauwe (2011) and Seppecher & Salle (2015), workers are divided into two main categories: the optimistic and the pessimistic ones. The probability of being optimistic depends on the employment status (whether the worker is employed or unemployed): with probability ψ the worker is optimistic if employed and pessimistic if unemployed, with probability (1 – ψ) the worker follows the "dominant opinion" of a small neighbourhood (Seppecher & Salle, 2015)[34]. The consumption functions are the following:

$$\begin{cases} P(opt = true |\, employed) = \psi \\ P(dominant\ opinion |\, unemployed) = (1 - \psi) \\ P(pes = true |\, unemployed) = \psi \\ P(dominant\ opinion |\, employed) = (1 - \psi) \end{cases} \quad (21)$$

[33] Consistently with Dosi et al (2015), credit is paid back over a fixed time period. While Dosi et al (2015) assume that loans are paid back over 3 periods, this model adopts a more prudent rule by assuming that firms pay back their loans over 5 periods.

[34] By dominant opinion, it is meant the psychological state (either optimistic or pessimistic) of the majority of a *small neighbourhood*. This *small neighbourhood* is fixed and set randomly for each worker at beginning of the simulations.

$C_{i,W}{}^{opt}{}_{t}$ = (ε_1* $w_{i,t}$) + (ε_2 * $sav_{i,t-1}$) + (ε_3 * BI_t) (22)

$C_{i,W}{}^{pes}{}_{t}$ = (ε_4* $w_{i,t}$) + (ε_5 * $sav_{i,t-1}$) + (ε_3 * BI_t) (23)

$C_{i,Cap}$ = ($\varepsilon_6 * (Div^{C}{}_{i,t-1} + Div^{K}{}_{i,t-1} + Div^{cb}{}_{i,t-1} - tax^{cap}{}_{i,t}$))+ ($\varepsilon_7$ * $sav^{cap}{}_{i,t-1}$) (24)

Where $sav_{i,t-1}$ is the amount of savings of workers, BI_t is the basic income provided by the government to the unemployed, $Div^{C}{}_{i,t-1}$, $Div^{K}{}_{i,t-1}$ and $Div^{cb}{}_{i,t-1}$ are the dividends distributed by, respectively, consumption goods firms, capital goods firms and the commercial bank, $tax^{cap}{}_{i,t}$ is the amount of taxes paid to the government and $sav^{cap}{}_{i,t-1}$ is the amount of savings of capitalists.

4.2.5. Commercial bank

For the sake of simplicity, and following Assenza et al (2014) and Seppecher & Salle (2015), the model assumes that credit is supplied by a unique commercial bank. Moreover, workers and capitalists do not borrow money from banks, although households' credit is becoming more and more relevant to explain business cycles (Barba & Pivetti, 2009; Cynamon & Fazzari, 2013). The commercial bank supplies credit to consumption good firms that do not have sufficient liquidity to self-finance investments and production. For the sake of simplicity, and following again Seppecher & Salle (2015), the model assumes that the commercial bank does not select firms according to their level of risk: if a firm needs a loan, the bank supplies the requested loan at the current interest rate[35].

The interest rate is set by applying a mark-up on the Central Bank interest rate (Fontana & Setterfield, 2009; Dosi et al, 2015)

$i^{cb}{}_{t}$ = $i^{CB}{}_{t}$ * (1 + $m^{cb}{}_{t}$) (25)

The commercial bank provides credit to consumption good firms, at the current rate $i^{cb}{}_{t}$, to be paid pack during m = 5 periods. Furthermore, in order to fulfil reserves requirements, the commercial bank obtains unlimited advances by the Central bank, at the current rate $i^{CB}{}_{t}$, to be paid back during m = 3 periods. Reserves requirements consist of fixed share of deposits:

[35] At this stage, the model does not focus on the role of credit constraints in the business cycle in order not to add to much non linearity. Further developments of the model will however take into account a decentralized banking system with credit constraints.

$R^{*} = r * Dep^{cb}{}_{t}$ (26)

Therefore, advances required by the commercial bank to the central bank are equal to:

$Adv_t = \max(R^{cb} - R^{*}, 0)$ (27)

Commercial bank's profits are the sum of the interests paid by consumption goods firms minus the interests paid to the central bank on advances:

$\Pi^{cb}{}_{t} = \sum_{j=1}^{c}(int_{j,t}) - int^{Adv}$ (28)

Since the commercial bank cannot select firms on the basis of their riskiness, a share of net profits is retained in order to cover potential future losses. The amount of retained profits depends on the firms' aggregate ratio of debt over net capital: the higher the financial fragility of firms, the higher the share of profits retained by the bank to cover potential losses.

$\lambda^{cb}{}_{t} = \mu_4 * \sum_{i=1}^{n}((LB_{i,t-1} / NK_{i,t-1}) * \frac{1}{n})$ (29)

$RE^{cb}{}_{t} = \max(\Pi^{cb}{}_{t} * \lambda^{cb}{}_{t}, 0)$ (30)

When a firm goes bankrupt because liquidity is not sufficient to pay back the interests due to the bank, the bank is allowed to get the remaining liquidity of the firm and downgrading the remaining debt to be paid back in that period. Since defaulted firms "resuscitate" at the beginning of each time period, the firm will start with a positive debt consisting of the remaining liability.

4.2.6. Central bank

The Central Bank sets the interest rate according to a standard reaction function (Taylor, 1993; Clarida et al, 1999; Allsopp & Vines, 2000). In particular, following Dosi et al (2015), the model assumes two different regimes: a "hard-nosed" (De Grauwe, 2014) regime in which the central bank only targets a fixed inflation rate, and a "employment stability-oriented" regime in which the central bank sets the interest rate according to both an inflation target and an unemployment-target equally weighted:

$i^{CB}{}_{t} = i^{CB*}{}_{t} + (\eta_1 * (\dot{\bar{p}}_{t-1} - \dot{\bar{p}}^{T}) + (\eta_2 * (u^{*}{}_{t} - u_t))$ (31)

With $\begin{cases} \eta_2 = 0,\ \eta_1 = 1.1 & if\ hard - nosed \\ \eta_2 = 1.1,\ \eta_1 = 1.1 & if\ employment\ stability - oriented \end{cases}$ (32)

Where ${i^{CB*}}_t$ is the targeted interest rate, $\dot{\bar{p}}^T$ is the targeted inflation rate and ${u^*}_t$ is the targeted unemployment rate.

Since the Central bank provides at the current rate ${i^{CB}}_t$ all the liquidity required by the commercial bank, the profit function of the Central Bank is equal to:

$${\Pi^{CB}}_t = int^{Adv} \quad (33)$$

For the sake of simplicity, the model also assumes that the government owns the central bank. Hence, dividends are entirely distributed to the government.

4.2.7. Government

The Government receives central bank's profits, collects taxes from capitalists' dividends and supplies bonds purchased by the central bank in order to finance a basic income for the unemployed and pay back the interests on bonds[36]. The basic income is assumed to be the same for each worker and represents a fixed share of the current average wage:

$$tax_t = \sum_{i=1}^{m}(tr * Div_{i,t-1}) \quad (34)$$

$${BI^*}_t = ((\theta * \overline{w}_t) * U) \quad (35)$$

Where tr is the tax rate, $Div_{i,t-1}$ is the sum of all dividends received by capitalists, ${BI^*}_t$ is the desired government expenditure for providing all the unemployed with a basic income equal to ($\theta * \overline{w}_t$) and U is the unemployed labour force.

As in Dosi et al (2015), the government selects two alternative fiscal regimes (which are exogenous in the model). In the first fiscal regime, the Government is forced to follow the Maastricht criteria and keep the deficit to GDP ratio below 3%, and if the targeted basic income is not financially sustainable, it will first pay back the interests on bonds and then supply a lower basic income to the unemployed according to the fiscal constraint; in the second fiscal regime, the Government is free to run a deficit without legal nor institutional

[36] In Riccetti et al (2013) the government is allowed to employ workers and pay wages. Since adding public workers would be more realistic but it would not change results qualitatively, the model is kept as simple as possible consistently wih Dosi et al (2015).

constraints; government expenditure will be equal to the interests on bonds plus the targeted basic income.

$$GE_t = tax_t + \Pi^{CB}{}_{t-1} + (GDP_{t-1} * def^*) \quad (36)$$

$$def^* = (\omega * 0.03) + \left((1 - \omega) * \frac{(BI_t{}^* + (i^G * B) - tax_t - \Pi^{CB}{}_{t-1})}{GDP_{t-1}}\right) \quad (37)$$

Where def^* is the desired deficit to GDP ratio, $(i^G * B)$ are the interests paid on bonds and ω is a variable that takes value 1 if the government is constrained to follow the 3% rule and 0 otherwise. For the sake of simplicity there are only one year bonds.

4.3.Simulations and results of the model

Since the aim of this model is to analyse the aggregate effect of non-linear investment decisions by focusing explicitly on the relationship between the rate of capacity utilization and the rate of capital accumulation within different fiscal and monetary regimes, there are two baseline scenarios with linear investment decisions ($\gamma_{4,t} = C$, $\gamma_{5,t} = 0$) and non-linear investment decisions, assuming restrictive fiscal and monetary regimes. In particular, the baseline scenario includes a hard-nosed monetary authority ($\eta_2 = 0$) and an austerity-constrained fiscal authority that is committed to keep the public deficit to GDP ratio below 3%[37]. Starting from these baseline scenarios, there are 3 alternative scenarios (Dosi et al, 2015). In the first scenario, fiscal authorities are austerity-constrained while the monetary authority is concerned with both price stability and full employment. In the second scenario, fiscal authorities are free to finance public expenditure without institutional constraints while the central bank is only concerned with price-stability. In the third scenario, the monetary authority is concerned with both full-employment and price stability and fiscal authorities are free to finance government expenditure without institutional constrains. Results are eventually compared in order to conclude on the different role that fiscal and monetary policies play when investment decisions are either reversible or irreversible.

Each scenario is simulated over 1500 periods and only the last 1000 periods are retained for the analysis: first 500 periods are dropped for statistical robustness concerns (Grazzini, 2012). We perform 20 Monte Carlo simulations for each scenario and compute the across-

[37] The values of the parameters of the model are provided in Appendix 1,

simulations means of the key variables[38]. We then perform a statistical analysis of the emergent statistical properties for each scenario.

4.3.1. Results of the simulations in the irreversible-investments scenarios

Rate of Utilization		*Fiscal Policy*	
		Austerity	*No Constraints*
Monetary Policy	*Hard-nosed*	1	Mean: 1.029 S.D.: 0.677
	Employment-stability oriented	Mean: 1.02 S.D.: 0.916	Mean: 1.03 S.D.: 0.706

Table 4.1: The rate of utilization with non-linear investment decisions;

Unemployment		*Fiscal Policy*	
		Austerity	*No Constraints*
Monetary Policy	*Hard-nosed*	1	Mean: 0.645 S.D.: 0.619
	Employment-stability oriented	Mean: 0.756 S.D.: 0.862	Mean: 0.615 S.D.: 0.638

Table 4.2: The rate of unemployment with non-linear investment decisions;

[38] Each scenario implies 20 Monte Carlo runs of 1000 periods each. After each run, the averages of key variables are computed; at the end of the 20 runs, the across-runs averages are computed and provided in the tables.

Capital Accumulation		*Fiscal Policy*	
		Austerity	*No Constraints*
Monetary Policy	*Hard-nosed*	1	Mean: 1.094 S.D.: 0.622
	Employment-stability oriented	Mean: 1.071 S.D.: 0.778	Mean: 1.105 S.D.: 0.611

Table 4.3: The rate of capital accumulation with non-linear investment decisions

Tables 4.1 to 4.3 show the results of the simulations, when investment decisions are non-linear, in the four policy scenarios. The first window provides the results of the simulations for the baseline scenario, when the government commits to keep the deficit to GDP ratio below 3% and the central bank pursues the *hard-nosed* price-stability rule[39]. If we look at the first column of tables 4.1, 4.2 and 4.3, we can see that if the monetary rule changes and the central bank commits to price stability *and* full-employment at the same time, the rate of utilization increases together with the rate of growth, and the unemployment rate falls. Furthermore, the standard deviation tends to fall when the central bank commits to employment stability, suggesting that an expansionary monetary policy can stabilize the cycle around more effective equilibria. These results can be explained by the expansionary characteristics of a lower interest rate. For instance, when the government is hand-tied by austerity measures the unemployment rate is significantly higher than the full employment target. To the extent that the gap between the actual and the targeted rate of unemployment is higher than the gap between actual and targeted inflation, the interest rate set by the central bank is substantially lower than the rate set under a “hard-nosed” regime. The fall in the interest rate has a double effect on this artificial economy: on one hand, it reduces the real rate of interest and thereby the burden of debt for firms, which can achieve now higher rates of profit and reinvesting a share of them. Furthermore, the fall in the real rate of interest implies a fall in the mark-up and, by this channel, a more favourable distribution of income to workers, who have the higher propensity to consume out of income. The higher rate of profit and the higher rate of utilization triggered by the fall in the real rate of interest imply a better performance for the economy as a whole.

[39] The values in the tables are always provided relative to the baseline scenario. Since the first window shows the results of the baseline scenario, mean and variance are by definition equal to 1.

If we look at the first row in tables 4.1, 4.2 and 4.3 we can observe the relative effect of more expansionary fiscal policies. To the extent that the government is no longer forced to respect the 3% rule of deficit over GDP, countercyclical fiscal policies can significantly increase both the rate of utilization and the rate of growth, as well as reducing the rate of unemployment closer to the full employment target. Furthermore, the model is much more stable around the long run trend with respect to both the baseline scenario and the second alternative scenario in which the government commits to austerity measures with an employment stability-oriented central bank. This result suggests that fiscal policies are much more effective than monetary policies in stabilizing the cycle and improving the economic performance. This result can be explained through the direct impact of fiscal policies over aggregate consumption. For instance, increasing consumption implies increasing the rate of capacity utilization and, consequently the rate of profit, with a positive effect on capital accumulation.

Eventually, if we look at the second row and second column of tables 4.1, 4.2 and 4.3 we observe that as long as the government does not commits to austerity and the central bank commits to employment stability, the economy performs much better than in the three previous scenarios. In this scenario, the unemployment rate is consistently lower and the rates of capacity utilization and capital accumulation are significantly higher with respect to the baseline scenario.

We can conclude so far that fiscal policies perform better than monetary policies in stabilizing the cycle and reducing the waste of productive resources. Furthermore, we get to the Keynesian conclusion that a mix of expansionary fiscal and monetary policies is the “optimal” economic policy rule in order to guarantee better economic performances and higher stability.

Tables 4.4 to 4.6 show the results of the simulations in the four policy scenarios when non-linear investment functions are replaced by linear investment functions. We can observe that the policy conclusions are almost equivalent with respect to the non-linear investment scenarios: an expansionary fiscal policy is preferable to an expansionary monetary policy, and a mix of expansionary fiscal and monetary policies is the “optimal” policy mix. However, the differences in term of economic stability are significant: fiscal and monetary policies have a lower stability impact with respect to the baseline scenario, as suggested by the lower standard deviation differentials across policy scenarios. The reason is that the standard deviation in the baseline scenario (austerity government and price-stability oriented central bank) is lower when investment functions are linear. The impact of demand policies is relatively low since the economy is already relatively stable with respect to the non-linear scenario.

Rate of Utilization		*Fiscal Policy*	
		Austerity	*No Constraints*
Monetary Policy	*Hard-nosed*	1	Mean: 1.018 S.D.: 0.74
	Employment-stability oriented	Mean: 1.012 S.D.: 1.014	Mean: 1.02 S.D.: 0.776

Table 4.4: rate of utilization, relative to the baseline, with linear investment functions

Unemployment		*Fiscal Policy*	
		Austerity	*No Constraints*
Monetary Policy	*Hard-nosed*	1	Mean: 0.721 S.D.: 0.718
	Employment-stability oriented	Mean: 0.813 S.D.: 0.989	Mean: 0.694 S.D.: 0.748

Table 4.5: rate of unemployment, relative to the baseline, with linear investment functions

Capital Accumulation		*Fiscal Policy*	
		Austerity	*No Constraints*
Monetary Policy	*Hard-nosed*	1	Mean: 1.06 S.D.: 0.847
	Employment-stability oriented	Mean: 1.045 S.D.: 0.932	Mean: 1.067 S.D.: 0.864

Table 4.6: rate of capital accumulation, relative to the baseline, with linear investment functions

4.3.2. Statistical emergent properties: stationarity and non-ergodicity

By performing a unit root test on the time series, in both cases with linear and non-linear investment functions, it is possible to reject at 100% the null hypothesis of a unit root, suggesting that all series are strictly stationary. Since non-stationarity is a sufficient but not necessary condition to reject the null-hypothesis of ergodicity (Cross, 1993B), a structural breaks analysis on the time series allows to check whether a unique absorbing equilibrium exists or whether a set of transient, endogenous equilibria dominate the long run behaviour of the model. For instance, if we find no structural breaks we cannot reject the null hypothesis of ergodicity, if however we find significant structural breaks we can rule out the existence of a unique, absorbing long-run equilibrium and conclude that multiple endogenous and transient statistical equilibria characterize the dynamic behaviour of the model. In particular, the Bai-Perron structural break analysis (Bai & Perron, 1998) allows detecting endogenously the number of structural breaks in time series. By imposing a standard trimming percentage of 15% we obtain the results in tables 4.7 and 4.8.

Rate of Unemployment								
Scenarios	1		2		3		4	
Information criteria	Sc.	LWZ	Sc.	LWZ	Sc.	LWZ	Sc.	LWZ
Mean Breaks	3,2	1,6	1,1	0,1	0	0	0	0
P(Breaks = 0)	0	0,2	0,3	0,9	1	1	1	1
P(Breaks >=2)	0,9	0,6	0,25	0	0	0	0	0
Rate of Capital Accumulation								
Scenarios	1		2		3		4	
Information criteria	Sc.	LWZ	Sc.	LWZ	Sc.	LWZ	Sc.	LWZ
Mean Breaks	3,8	3,15	3,2	1,2	2,4	0,25	1,2	0
P(Breaks = 0)	0	0,05	0	0,25	0,15	0,8	0,3	1
P(Breaks >=2)	1	0,95	0,9	0,4	0,75	0,05	0,4	0
Rate of Utilization								
Scenarios	1		2		3		4	
Information criteria	Sc.	LWZ	Sc.	LWZ	Sc.	LWZ	Sc.	LWZ
Mean Breaks	2,65	0,9	0,8	0,05	0	0	0	0
P(Breaks = 0)	0,05	0,45	0,5	0,95	1	1	1	1
P(Breaks >=2)	0,85	0,3	0,2	0	0	0	0	0

Table 4.7: Structural breaks analysis of the model with non linear investment functions

Rate of Unemployment								
Scenarios	1		2		3		4	
Information criteria	Sc.	LWZ	Sc.	LWZ	Sc.	LWZ	Sc.	LWZ
Mean	1,7	0	0,3	0	0	0	0	0
P(Breaks = 0)	0,2	1	0,75	1	1	1	1	1
P(Breaks >=2)	0,4	0	0,05	0	0	0	0	0
Rate of Capital Accumulation								
Scenarios	1		2		3		4	
Information criteria	Sc.	LWZ	Sc.	LWZ	Sc.	LWZ	Sc.	LWZ
Mean	3,25	0,85	1,6	0,4	0,3	0,05	0,15	0
P(Breaks = 0)	0	0,4	0,25	0,7	0,75	0,95	0,95	1
P(Breaks >=2)	0,85	0,2	0,45	0,1	0,05	0	0,05	0
Rate of Utilization								
Scenarios	1		2		3		4	
Information criteria	Sc.	LWZ	Sc.	LWZ	Sc.	LWZ	Sc.	LWZ
Mean	1,15	0	0,25	0	0	0	0	0
P(Breaks = 0)	0,4	1	0,8	1	1	1	1	1
P(Breaks >=2)	0,25	0	0,05	0	0	0	0	0

Table 4.8: Structural breaks analysis of the model with linear investment functions

We can observe in tables 4.7 and 4.8 that in both the non-linear and the linear models the probability not to find structural breaks in the baseline scenario (scenario 1) is close to 0, suggesting that there are other non-linearities and persistencies, besides the investment function, that dominate in the long run dynamic (i.e. *animal spirits*, optimistic/pessimistic consumption patterns and the long term structure of debt). Nevertheless, in the linear case the structural variability is much weaker: if we look at the LWZ information criterion, only the rate of accumulation suffers structural breaks in 40% of the estimated time series, while for the rate of unemployment and the rate of capacity utilization we can never reject the null hypothesis of ergodicity, whatever the random seed. The reason is that in this artificial economy firms invest according to the rate of utilization as well as the rate of profit. Since firms pay back their debt over n=5 years, even though the linearity of investment decisions allows to disinvest more easily, the rate of profit tends to be less reactive than the rate of utilization. For instance, 20% of unemployment time series do not exhibit any structural break at all, and 40% of them display only one structural break over 1000 periods. The same applies for the rate of utilization: 75% of time series display one structural break at most. These results can also be observed in figures 4.4 to 4.9. Figures 4.4 to 4.6 show the dynamics of the key variables in the non-linear investment functions baseline scenario, while figures 4.7 to 4.9 show the dynamics of the same key variables when investment decisions are linear.

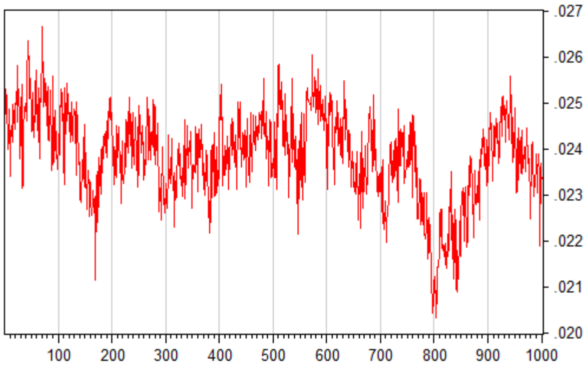


Figure 4.4: rate of capital accumulation in the non-linear, baseline scenario

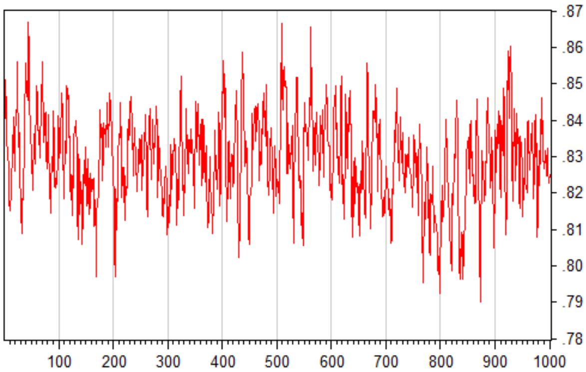


Figure 4.5: rate of capacity utilization in the non-linear, baseline scenario

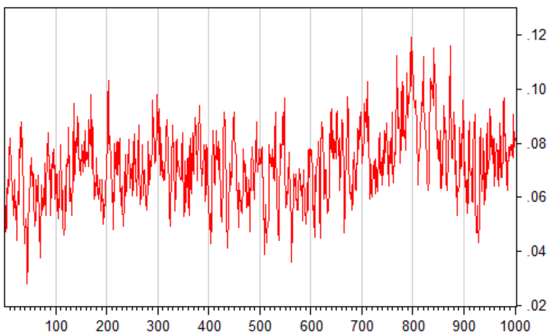


Figure 4.6: rate of unemployment in the non-linear baseline scenario

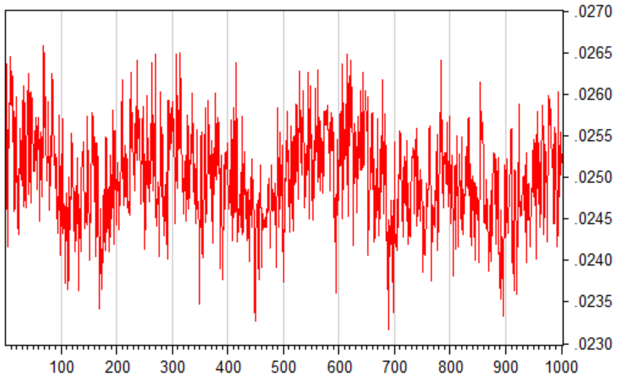


Figure 4.7: rate of capital accumulation in the linear, baseline scenario

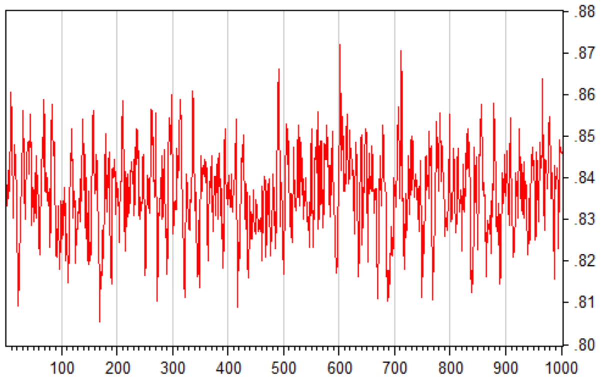


Figure 4.8: rate of capacity utilization in the linear, baseline scenario

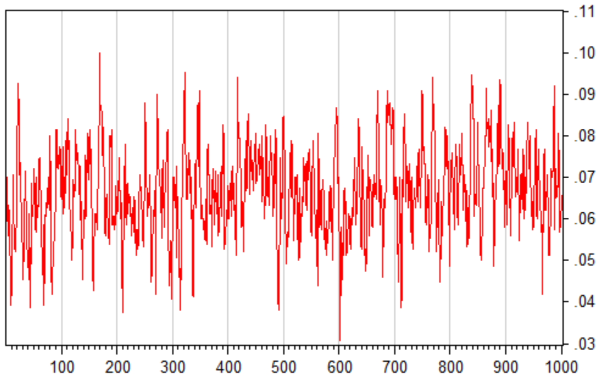


Figure 4.9: rate of unemployment in the linear, baseline scenario

When investment functions are non-linear, fluctuations are much more asymmetric and equilibria become fully endogenous: rather than observing a unique long run trend, we can observe several equilibria that emerge endogenously according to the business cycle. In particular, we can observe that recessions can last for a long time by triggering a new equilibrium characterized by high unemployment and slow growth. This artificial economy is characterized by a strong instability and a strong sensitiveness to structural changes. When we look at figures 4.7 to 4.9, we can observe that fluctuations look more symmetric and less *hysteretic*: the dynamics of this artificial economy seem to reflect a strong *persistence* rather than structural variability.

It is interesting, however, to see how the model evolves when different fiscal and monetary rules are taken into account. We can observe for instance that as long as the monetary policy rule changes and the central bank commits to full employment, in the linear model only 30% of the estimated time series for capital accumulation suffer structural breaks, 70% of the estimated time series do not allow to reject the null-hypothesis of ergodicity. In other words, a full-employment-oriented monetary policy is able to stabilize the economy around a fixed equilibrium. This is not the case in the non-linear model: 75% of the estimated time series for the rate of accumulation still exhibit structural breaks. As regards the rate of unemployment and the rate of capacity utilization, the Schwartz and the LWZ information criteria seem to offer two different conclusions: the first criterion still detects structural breaks, while according to the second one we can reject the null hypothesis of ergodicity.

The third scenario is the most significant: in the linear case, both criteria suggest not to reject the null hypothesis of ergodicity for all the time series. In the non-linear case, however, the rate of capital accumulation still exhibits structural breaks. This situation is confirmed in the last scenario: expansionary fiscal and monetary policies cannot fully eliminate the effect of non-linearities and persistencies on the structure of the economy, since the Schwartz criterion still detects structural breaks.

Hence, as long as investment decisions are non-linear and fiscal and monetary authorities are, respectively, austerity-constrained and price-stability oriented, the economy tend to be fundamentally *hysteretic* and exhibits structural breaks: slow but long-lasting booms are systematically followed by rapid and slowly recoverable recessions. When, however, countercyclical fiscal and monetary policies are introduced, the economy rapidly and almost systematically stabilises around full employment, although in the model characterized by non-linear investment functions there is still a structural variability in the rate of capital accumulation, according to the Schwartz information criterion. Hence, the mainstream asymptotically stable paradigm is valid in the case of expansionary and countercyclical fiscal and monetary policies that prevent the economy to stabilize around sub-optimal equilibria. Nevertheless, if monetary policies are merely price-stability oriented and fiscal policies are institutionally constrained, the economy becomes extremely unstable and characterized by asymmetric cycles and endogenous sub-optimal equilibria. Figures 4.10 to 4.12 show the rate of capital accumulation, the rate of capacity utilization and the rate of unemployment in the fourth scenario with expansionary fiscal and monetary policies. The dynamics of this artificial economy reflect a stronger stability with respect to figures 1 to 3: stationarity and ergodicity cannot systematically be rejected any longer.

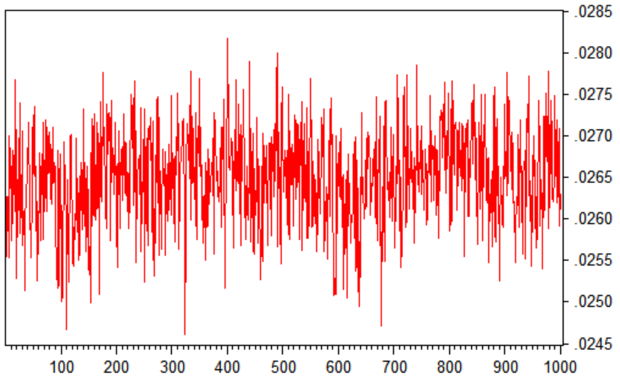


Figure 4.10: rate of capital accumulation in the fourth, non-linear scenario

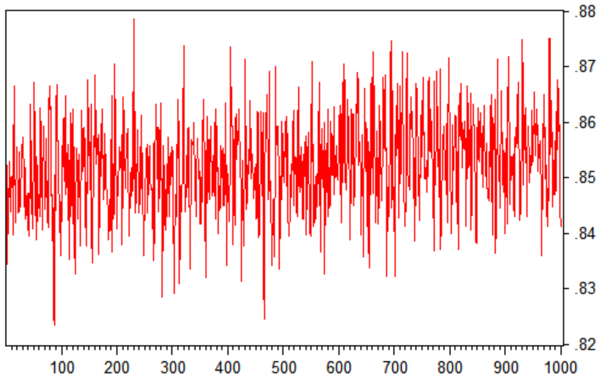


Figure 4.11: rate of capacity utilization in the fourth, non-linear scenario

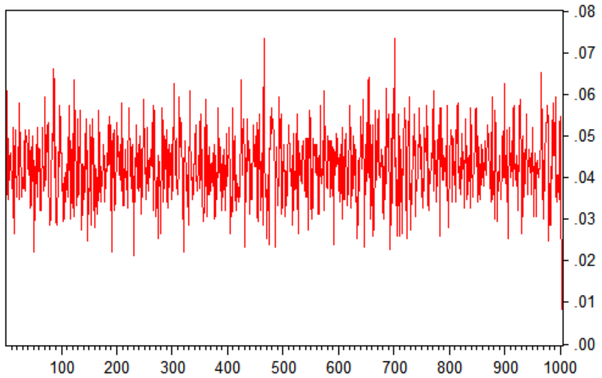


Figure 4.12: rate of unemployment in the fourth, non-linear scenario

4.4.Concluding remarks

Since the seminal paper by Dixit (1989), the existence of sunk costs and the consequent non linearity in investment decisions has become a non negligible issue. A stream of research (Bertola & Caballero, 1994; Abel & Eberly, 1999; Bloom, 2000; Veracierto, 2002; Kahn & Thomas, 2008) has focused on the explanatory power of non-linear investment functions to account for aggregate investment variability, while a second stream of research (Cross et al, 1993; Amable et al, 1993, 1995; Piscitelli et al, 1999, 2000; Serafini, 2001; De Peretti & Lang, 2009) has focused on the theoretical relevance of non-linearity to account for equilibrium endogeneity and, more specifically, hysteresis. While the first stream of research has mainly developed along with partial and/or general equilibrium models and concluded on the long run neutrality of micro non-linearity, the second stream of research has focused on the long run properties of non-linear investment functions in the framework of the original model of hysteresis (Preisach, 1935) without, however, integrating such a framework in larger macroeconomic models. This chapter developed an agent-based stock-flow consistent (AB-SFC) model with post-Keynesian foundations and non-linear investment functions *à la* Preisach (1935) in order to analyze the long run properties of the original model of hysteresis in a more general macroeconomic framework without general equilibrium constraints.

Non linear investment functions are able not only to generate persistent fluctuations but also to determine the emergent and transient equilibriums that, far from being exogenously determined, are strictly endogenous and path-dependent. For instance, non-linear investment functions are able to generate both prolonged periods of booms and severe recessions, and to account for the long run persistence of the effects of temporary shocks, namely persistently lower rates of growth and higher rates of unemployment. In this framework, business cycles are not the consequence of a linear process of capacity adjustment to exogenous demand shocks, they are the consequence of discontinuous adjustments of productive capacity as a response to demand variations that are generated by the interaction among heterogeneous firms: optimistic or sunk-costs constrained firms that suddenly increase productive capacity, and pessimistic or over-indebted firms that were “coerced to invest” and suddenly revise downwards their investment plans. Therefore, fluctuations are fully endogenous and driven by demand.

Expansionary fiscal and monetary regimes are not only able to substantially reduce unemployment and foster economic growth, but they have also a fundamental stabilizing effect: to the extent that temporary shocks are rapidly absorbed, the frequency of firms that radically revise their investment plans is substantially reduced, and the economy can stabilize around a unique, absorbing equilibrium. In absence of expansionary fiscal and monetary policies, full employment is no longer an absorbing *state of rest*: multiple transient and statistical equilibria characterized by underutilization of productive capacity, slow growth and involuntary unemployment can emerge endogenously as a consequence of a fundamental instability and pro-cyclicality. These results are consistent with Ball (2009) and Stockhammer & Sturn (2012), who confirm econometrically the non-neutral effect of monetary policies on unemployment hysteresis, and with Cerra et al (2009), who find that monetary and fiscal stimulus affect the length of recovery after recessions. Furthermore, they are consistent with Schettkat & Sun (2009), who show that asymmetric monetary policies oriented towards price-stability can stabilize unemployment around persistently higher rates.

These effects, however, are not explained by unit roots or non stationary dynamics but rather by recurrent structural changes that modify the equilibrium conditions. Consequently, the model is globally stationary although characterized by endogenous structural changes. The importance of identifying hysteresis independently on unit roots is crucial. Most non stationary unemployment time series fail to display unit roots when the alternative hypothesis of structural break is explicitly tested (Arestis & Mariscal, 1999; Papel et al, 2000), suggesting that both stationary-ergodic and non stationary-non-ergodic models can hardly account for explaining the statistical properties of real time series. Developing more complex models of structural change and non-linear dynamics that are able to account for a larger variety of stylized facts with respect to both asymptotically stable and unit /zero root linear models is therefore increasingly important. From this point of view, this model represents an attempt to formalize micro-behaviors and simple heuristics that can explain how structural changes emerge endogenously, and to provide a "non obvious and realistic chain of causal links that might be useful to interpret real world events" (Valente, 2005).

Indeed, the scope of this model was essentially isolating the hysteresis effects of non-linear investment functions on business cycles and growth paths under different monetary and fiscal regimes. In order to do so, the model assumes a passive and accommodative banking sector, the absence of financial markets for firms and households, a simple process of technological development based on learning by doing instead of a more developed and realistic innovative environment characterized by decentralized R&D strategies and innovation-based competition. Introducing more complex banking rules and developing financial markets might allow, for instance, to analyze the reciprocal influence between “coerced investments” and firm’s financial instability (Crotty & Goldstein, 1992); the effects of households’ debt (Cynamon & Fazzari, 2013) and the effects of credit rationing on business cycles (Riccetti et al, 2013); or the possibility for firms producing with excess capacity to compensate low profits with financial returns in risky assets, by increasing financial fragility.

Further evolutions of this model might take into account more complex assumptions, namely: introducing credit rationing and more complex behavioral rules in the banking system. In Riccetti et al (2013), Dosi et al (2015) and Assenza et al (2014) banks are allowed to apply different interest rates to firms according to their riskiness, and rationing the credit to over-indebted firms. This mechanism would introduce a further element of pro-cyclicality and non linearity in the model by reinforcing hysteresis effects; Modeling R&D investments in both capital and consumption good sectors in the wake of Dosi et al (2015). This would contribute to shape the business cycles and add a further element of reality to the model. Introducing financial markets. In particular, the growing role of households’ debt and shadow banking activities in modern capitalist economies can no longer be neglected in macroeconomic models that aim to analyze the characteristics and properties of business cycles; Focusing more specifically on income distribution variables (Dosi et al, 2015) by distinguishing between profit-led and demand-led growth regimes (Napoletano et al, 2012).

Appendix 4.1: parameters' value

Description	Parameter	Value
Number of firms in consumption-goods sector	n	100
Number of firms in capital-goods sector	m	25
Number of workers	nw	1500
Number of capitalists	nc	15
Mark-up capital goods firms	m^K	0.04
mark-up commercial bank	m^{cb}	0.5
Reserves ratio of the commercial bank	r_c	0.05
Sensitivity of long run rate of profit to past realizations	ρ	0.8
Sensitivity of mark-up to firms' competitiveness	β_1	0.35
Sensitivity the mark-up to unemployment	β_2	0.1
Sensitivity of mark-up to firms' real interest rate	β_3	0.3
Animal spirits	γ_1	0, 0.01
Depreciation rate	γ_2	0.02
Sensitivity of investment to capacity utilization	γ_3	0.02
Growth/safety preference	γ_4	0.015
Sensitivity of investment to the rate of profit	γ_5	0.1
Labour productivity adjustment parameter	ε	0.4
Sensitivity of wages to firms' competitiveness	δ_1	0.04
Sensitivity of wages to labour productivity growth	δ_2	1
Sensitivity of wages to inflation	δ_3	0.1
Sensitivity of wages to unemployment	δ_4	0.3
Fixed coefficient of firms' retained earnings	μ_1	0.1
Sensitivity of firms' retained earnings to debt leverage	μ_2	0.3
Sensitivity of firms' retained earnings to past dividends	μ_3	4
Sensitivity of commercial bank's retained earnings to firms' leverage	μ_4	0.1
Sensitivity of central bank's interest rate to inflation gap	η_1	1.1
Sensitivity of central bank's interest rate to unemployment gap	η_2	0; 1.1
Propensity to consume out of wages (opt. workers)	ε_1	0.9
Propensity to consume out of wealth (opt. workers)	ε_2	0.3

Propensity to consume out of basic income (workers)	ε_3	1
Propensity to consume out of wages (pess. workers)	ε_4	0.8
Propensity to consume out of wealth (pess. workers)	ε_5	0.2
Propensity to consume out of dividends (capitalists)	ε_6	0.6
Propensity to consume out of wealth (capitalists)	ε_7	0.1
Probability of being optimistic/pessimistic	ψ	0.7
Growth preference's trigger value	a	~U(0.5,1)
Safety preference's trigger value	b	~ U(0.5,a)
Basic income share relative to average wage	θ	0.4
Tax rate	tr	0.1
Desired stores' ratio	s^*	0.1

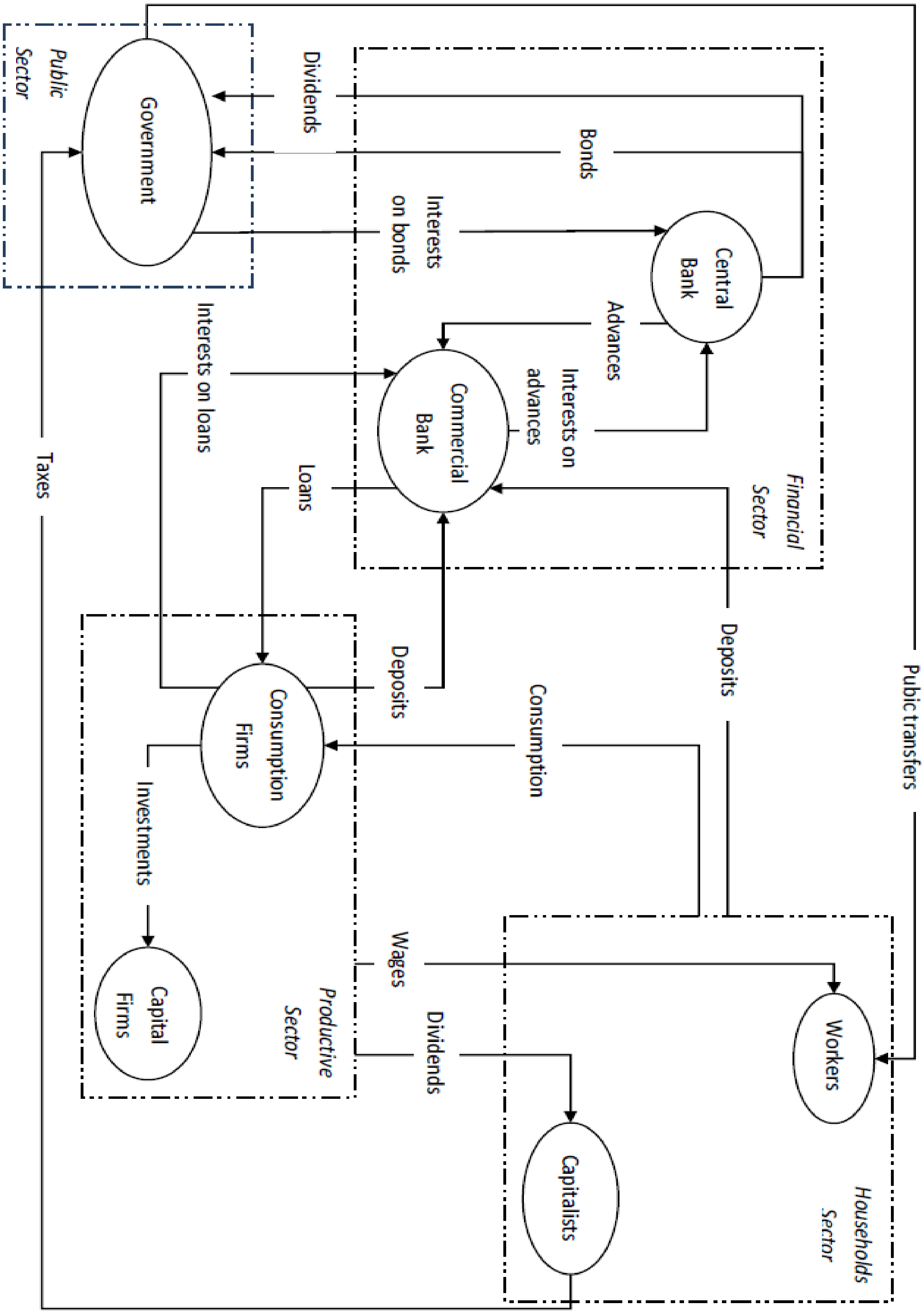
Appendix 4.2.1: balance sheet

	Capitalists	Workers	C Firms	K Firms	Commercial Bank	Central bank	Government	Sum
Deposits	+Dk	+Dw	+Dcf		-D	-Dg	+Dg	0
Shares	+S		-Scf		-Scmb			0
Inventories			+Invc					+Inv
Fixed Capital			+K					+K
Loans			-L		+L			0
Liquidity Reserves					-LR	+LR		0
Bonds						+B	-B	0
Balance	-Vk	-Vc	-Vc	0	-Vcmb	-Vcm	-Vg	-(Inv+K)
sum	0	0	0	0	0	0	0	0

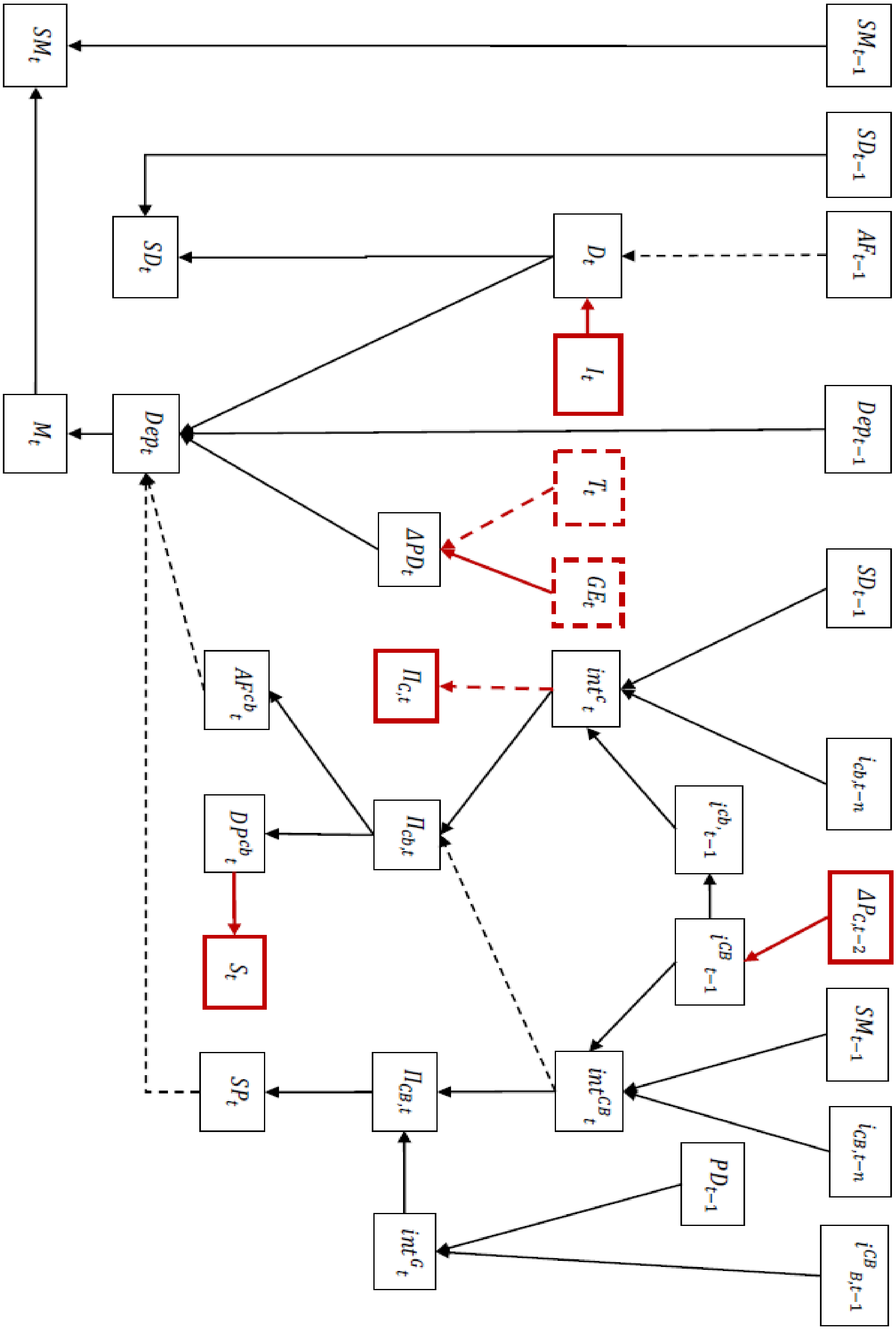
Appendix 4.2.2: transactions' matrix

	Capitalists	Workers	C Firms	K Firms	Commercial Bank	Central bank	Government	Sum
Consumption	- Ck	- Cw	+ C					0
Fixed Investment			- I	+ I				0
Inventory accumulation			+ Dinv, - Dinv					0
Taxes	- Tax						+ Tax	0
Government expenditure		+ GE					- GE	0
Wages		+ W	- W	- W				0
Entrepreneurial profits	+ EP		- EPc	- EPk				0
Commercial Bank profits	+ Pcmb				- Pcmb			0
Central Bank profits						- Pcb	+ Pcb	0
Interests on Loans			- ((rl-1)* Lc)		+ ((rl-1) * L)			0
Interests on Advances					- ((ra-1) * A)	+ ((ra-1) * A)		0
Interests on Bonds						+ ((rb-1) * B)	- ((rb-1) * B)	0
Changes in Bonds						- DB	+ DB	0
Changes in Liquidity Reserves					- LR	+ LR		0
Changes in loans			+ DLc		- DL			0
Changes in Deposits	- DDk	-DDw	- DDc		+ DDcmb	+ DDCB	-DDG	0
Changes in Shares	- DS * pS		+ DSc * pS		+ DScmb * pS			0
Loan defaults			+ (rl-1) * NPLc		- (rl-1) * NPL			0
Sum	0	0	0	0	0	0	0	0

Appendix 4.3: graphical representation of the circuit

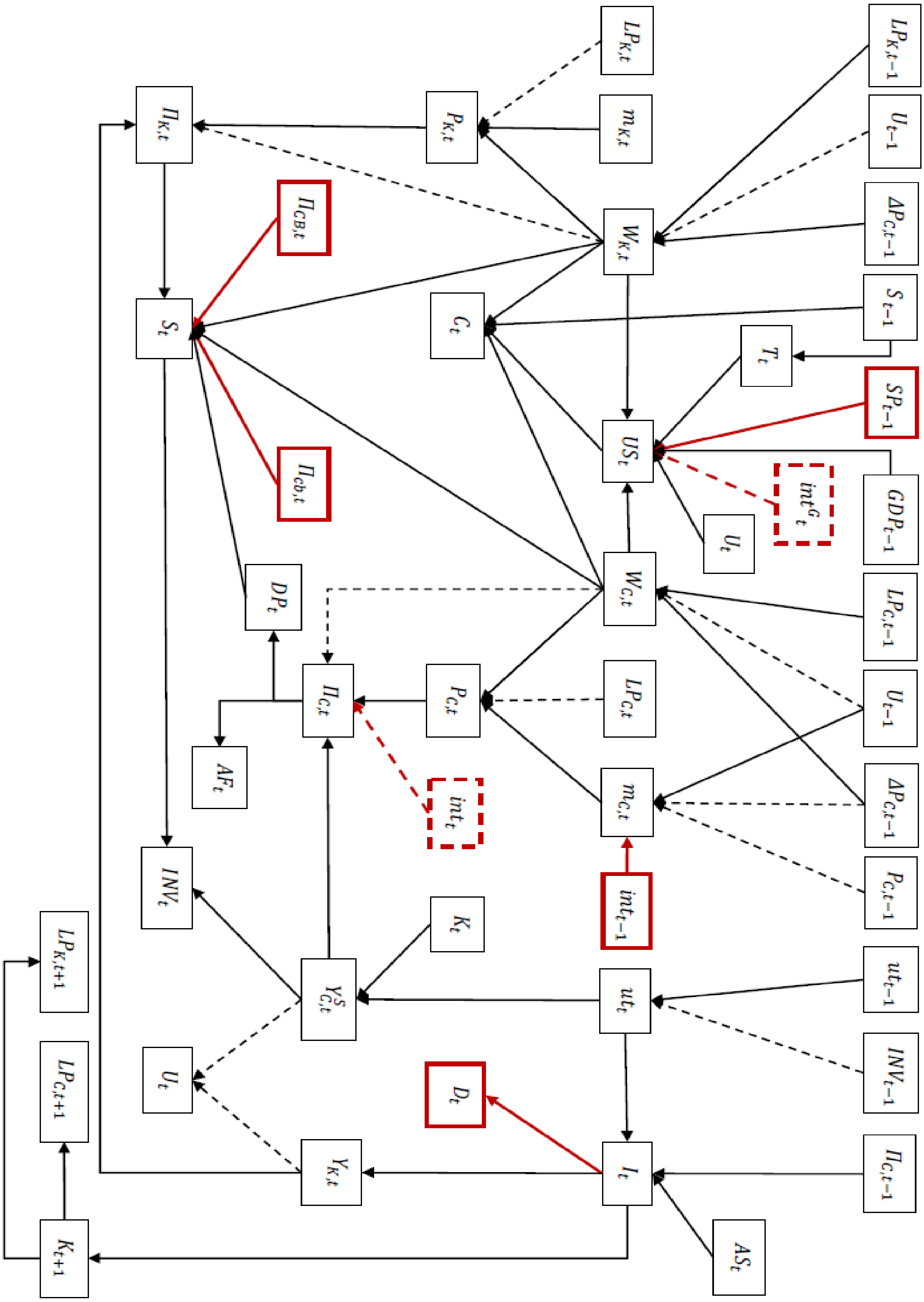


Appendix 4.4.1 : monetary flows diagram



Legend: dotted lines represent negative relationships; full lines represent positive relationships; red lines represent "real" variables affecting monetary variables;

Appendix 4.4.2: “real” flows diagram



Legend: dotted lines represent negative relationships; full lines represent positive relationships; red lines represent monetary variables affecting real variables;

General conclusion

Neoclassical macroeconomics developed historically around the organizing concept of equilibrium, a fixed and asymptotically stable *centre of gravity*. By assuming the existence of a *natural* rate of interest, a *natural* rate of unemployment or a *natural* output, the Neoclassical paradigm concentrated on the transitory divergences between actual realizations and structural equilibria, providing a strict theoretical dichotomy between short run disequilibrium phases and long run steady states or balanced growth paths. Recent developments in mainstream macroeconomics hold the legacy of the Neoclassical methodological paradigm. By replacing *natural* and *non-accelerating inflation* rate of unemployment with *natural* and *potential* output, the Real business cycles (RBC) and the Dynamic stochastic general equilibrium (DSGE) frameworks are methodological equivalent to the NRU or NAIRU approaches. By construction, the economy constantly gravitates around a non-accelerating inflation rate of capacity utilization (NAIRCU) or *potential output*, which is fully exogenous and solely determined by supply factors (Gordon, 1998; Nahuis, 2003).

The macroeconomic analysis performed by most international financial and academic institutions, including the International monetary fund (De Masi, 1997), relies on these frameworks. In their models, aggregate demand shocks generate transitory deviations that the rational representative agents (household, firm) - which maximize a utility or profit function - and the central bank - which commits to an optimal countercyclical monetary policy rule (Taylor, 1993, 2000; Clarida et al, 1999) - will eventually neutralize: at the end, output adjusts back to *potential output* without any long run consequence. Only supply side persistent shocks can affect potential output permanently[40], since there are generally no explicit feedbacks from demand to supply, except for few specific models (Stadler, 1990; Annichiarico et al, 2011 among others). Therefore, business cycles are interpreted as transitory deviations from the supply-side determined balanced growth path.

[40] In Dynamic stochastic general equilibrium models, stochastic shocks to *potential* output include supply-side shocks, namely technology and wage- or price-mark-up disturbances, and demand shocks, namely real exchange rate, interest rate or autonomous expenditure disturbances. Demand-side disturbances are generally transitory and have no permanent effect; permanent changes to potential output therefore are generated by permanent supply-side shocks, consistently with the Real business cycle (RBC) approach (Vetlov et al, 2011).

Empirical evidence regarding last decades suggests that large demand shocks can affect permanently both output and unemployment. Mainstream models explain this possibility by introducing a multiplicity of short/medium run equilibria that exhibit a form of path-dependence (Layard et al, 1991; Gordon, 1997, 1998; Richardson et al, 2000; Ball & Mankiw, 2002). All these approaches rationalize persistent fluctuations without rejecting the long run asymptotic stability framework – and the exclusive supply-side determination of the long run equilibrium (see Lang and Setterfield, 2012).

An alternative explanation for large and persistent fluctuations relies on the concept of *hysteresis*. By allowing transitory demand fluctuations to affect the long run trajectory of the economy permanently, the traditional paradigm of asymptotic stability is rejected. Nevertheless, different models of hysteresis imply different degrees of rejection. Section 2 showed that linear models of hysteresis (Kapadia, 2005; Kinzler & Schmid, 2014) are not able to modify the long run properties of asymptotic stability and aggregate demand neutrality when monetary authorities target a stable rate of inflation. Therefore, introducing unit-root persistence into DSGE or "new consensus" models does not change the asymptotic stability property of the equilibrium substantially. Only supply side shocks can affect the standard implications of non-hysteretic models, since transitory demand shocks would have no effect whatsoever on the long run equilibrium (Fontana & Palacio-Vera, 2005; Lavoie, 2006;).

Introducing non-linear and discontinuous investment decisions in these models implies that transitory supply and demand shocks exhibit permanent and non-reversible effects on the long run equilibria, in spite of the commitment of monetary authorities to target a fixed rate of inflation. It is therefore possible to reject the asymptotic stability assumption and the standard short-run/long-run dichotomy: equilibria are fully endogenous and hysteretic. Given the excessive emphasis of the mainstream approach on rationality and asymptotic stability, which patently contrasts with an alternative theory of hysteresis, we developed a Post-Keynesian agent-based model of growth and distribution with *genuine* hysteresis in section 3. In this framework, by introducing discontinuous investment functions, transitory demand fluctuations permanently affect the long run trajectory. Moreover, the economic interpretation of business cycles is radically different from traditional DSGE or "new consensus" models: instead of focusing on long run stability and short run divergence of the output gap, the model provides a continuum of endogenous and transient equilibria that imply different degrees of capacity utilization. There is no long run *normal* rate of capacity utilization or NAIRCU in this model; effective demand plays a central and crucial role, in accordance with

Keynesian/neo-Kaleckian frameworks. Section 4 develops the model of section 3 in a more complex dynamic framework by introducing fiscal and monetary policies. In this model, heterogeneous and discontinuous investment decisions of bounded rational managers, who seek to solve the fundamental growth-safety trade off (Crotty, 1993) in a radical uncertain environment, generate endogenous business cycles and structural change. The economy fluctuates and stabilizes within a continuum of degrees of capacity utilization without converging towards a unique and *absorbing* normal rate. Moreover, fiscal and monetary policies appear fundamental to stabilize the economy and prevent long lasting periods of low utilization of productive capacity, slow growth and high unemployment.

The aim of this thesis was to provide a different theoretical interpretation of business cycles with respect to the mainstream impulse/propagation and short-run/long-run dichotomies. Endogenous business cycles replace the exogenous and stochastic shocks that characterize the DSGE and RBC frameworks; the "organizing concept" of general equilibrium loses its relevance if endogenous structural changes characterize the long run dynamic of the economy. The importance of historical time, largely neglected in models exhibiting asymptotic stability, and the centrality of aggregate demand in long run growth are central concerns in these models. The seminal papers by Nelson & Plosser (1982) and Perron (1989) show that different models providing radically different interpretations and representations of the real world can explain the same empirical observation. Nevertheless, the recognition that several models might account for common empirical observations does not exclude that some of these models, because of their reductionist assumptions and theoretical abstractions, might be less appropriate to describe and represent the specific object of analysis that they attempt to explain (Lang & Setterfield, 2007). Economic models grounded on the concept of "general equilibrium", for example, might be able to represent hysteretic real world dynamics by assuming, for example, a set of stochastic shocks leading the system to constantly fluctuate around the "general equilibrium". On the basis of the theoretical implications of these models, it might be possible to estimate this "general equilibrium" as a moving average of real trends and argue that the whole paradigm is (internally) consistent and able to reproduce empirical stylized facts. However, if historical time is intrinsically irreversible and non-ergodic, an analysis based on "general equilibrium" (hence on a perfectly and entirely reversible logical time) represents an excessive effort of reductionism that eventually *betrays* the object of analysis itself. Therefore, *Conformity to what we can perceive of reality* is a criterion among others to validate a theoretical model, but it certainly doesn't allow, *per se*, accepting a model and the consequent reproduction and characterization of real world dynamics that it implies. Quoting Valente (2005), "if we adopted the validation process of mere quantitative criterion, we would not be able to assess which model, among many different one, is "correct"." (ibid, p. 17).

Finding the accurate model (if any) to represent what we can perceive from reality is beyond the scope of this thesis, which aimed instead at providing an alternative explanation of observed stylized facts based on the model of "genuine" hysteresis. The development of complex econometric tools able to detect structural changes and non-ergodic dynamics, for instance, opens the path to theoretical research that rejects the neoclassical paradigm of asymptotic stability in favor of a more complex paradigm of hysteresis. The model of *genuine* hysteresis reproduces non-ergodic macro-dynamics, hence it is able to account for both stationary and non-stationary time series (Amable et al, 2004). This is not the case for asymptotically stable models, which require stationarity and fail to account for empirical observations of non-stationarity; it is not even the case for unit root models, which require non-stationarity, and fail to detect hysteresis if empirical time series are stationary. The model of genuine hysteresis, from this point of view, is able to fit with a larger variety of observed macro-dynamics and it is therefore of a more general application. Moreover, it provides a radically different economic interpretation of business cycles: to the extent that the model is non-ergodic and not mean reverting (De Peretti, 2007), it allows rejecting the hypothesis of *natural* and *absorbing* equilibria in favor of a variety of possible *transient* equilibria[41] that are fundamentally endogenous and path-dependent.

When introduced within a Post-Keynesian/Kaleckian macroeconomic model, *genuine* hysteresis can account for several stylized facts, namely persistent fluctuations and structural change (Perron, 1989), chronicle excess capacity (Crotty, 2002), long run non-neutrality of monetary policies (Ball, 2009; Schettkat & Sun, 2009). Little emphasis is given in mainstream literature to fiscal policies (Setterfield, 2007), which are often considered as inflationary and destabilizing (Taylor, 2000B). Monetary policy is able alone to bear the burden of stabilizing the economy, except in particular circumstances. Consistently with Setterfield (2007) and Dosi et al (2015), this thesis aimed also at analyzing the role of fiscal policies when the monetary channel has no direct effects on aggregate consumption and only partially affects

[41] A state of a dynamic system is said *absorbing* if the system will always converge to it whatever the initial position. In this case, the probability to come back, sooner or later, to this state is equal to 1. A state of a dynamic system is said *transient* if the system has a positive probability to abandon this state and converge towards a different one.

investment decisions, which are fundamentally discontinuous and mainly determined by aggregate demand expectations. Results are consistent with Setterfield (2007) and Dosi et al (2015), finding a strong and long run effect of fiscal policies to smooth business cycle and stabilize the economy close to the full employment of resources.

Possible evolutions of the model might take into account: the possibility to introduce different interest rates according to the riskiness of firms and credit rationing (Riccetti et al, 2013; Assenza et al, 2014): the possibility for households to finance consumption through debt (Cynamon & Fazzari, 2013); the possibility for firms to invest in product and process innovation (Dosi et al, 2015)[42]. Moreover, further developments might take into account the role of fiscal policies in a more structural perspective, by taking into account their effect on firms' innovation success and aggregate technological change (Gallino, 2003; Mazzucato, 2015). Although raising the level of complexity is always possible, this thesis aimed specifically at concentrating on the non-linear and hysteretic effects of discontinuous investment functions on business cycles and long run trajectories, suggesting an alternative interpretation of aggregate macro-dynamics based on non-ergodicity and endogenous structural change, with all its policy implications.

[42] See the concluding remarks of section 4 as regards more detailed possible evolutions of the model

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Abstract

The neoclassical theory developed historically around the concept of (partial or general) equilibrium, by assuming its long run stability and independence from monetary and real fluctuations. The growing emphasis on path-dependence and, particularly, on the concept of *hysteresis* calls into question the traditional method, by rejecting the theoretical validity of the neoclassical equilibrium and its related stability properties. This thesis focuses on the model of “genuine” hysteresis, which first developed in the field of physics and recently extended its application to economic phenomena. Far from suggesting an appropriation of the methods that are typical of “hard” sciences, the aim is to analyse the consequences of discontinuous and hysteretic investment decisions on business cycles and long run trajectories. By relying on the Post Keynesian theory of growth and distribution, and the multi-agent methodological approach, this thesis develops a macroeconomic theoretical model that is able to generate non-linear business cycles around transitory equilibria, which are fully endogenous and historically determined according to the specific adjustment path. This theoretical framework confirms and reinforces the traditional Post Keynesian implications of income inequalities on the degree of utilization of productive capacity and on long run growth. Moreover, expansionary demand policies regain a central role in driving the economy towards the full employment of productive resources.

Résumé

La théorie économique néoclassique a historiquement évolué autour du concept d’équilibre (partiel ou général), supposé stable à long terme et indépendant des fluctuations monétaires ou réelles autour de l’équilibre même. L’attention plus récente vers le principe de dépendance au sentier et, en particulier, l’émergence du concept d’hystérèse en économie, remet en cause les propriétés de ces équilibres, notamment en ce qui concerne l’unicité, la stabilité et l’indépendance par rapport aux fluctuations. La thèse se concentre sur le modèle dit d’hystérèse « véritable », qui a ses origines dans la physique. Loin de promouvoir une approche scientifique « dure » en l’économie, il s’agit d’analyser les conséquences des discontinuités d’investissement des entreprises sur les fluctuations et sur les trajectoires de long terme. A’ travers l’approche théorique Postkeynésienne et l’approche méthodologique multi-agents, la thèse développe un modèle qui est capable de générer des fluctuations non linéaires autour d’équilibres purement transitoires, c’est à dire qui s’établissent de manière endogène à partir des sentiers d’ajustement effectivement entrepris. Dans ce cadre analytique, on retrouve renforcées les implications Postkeynésiennes de l’inégalité dans la distribution du revenu, sur l’utilisation des capacités productives existantes et sur le taux de croissance de l’économie. De surcroit, les politiques économiques de relance dites keynésiennes regagnent une place centrale sur le court ainsi que sur le long terme.