UNIVERSITY OF GOTHENBURG
School of Business, Economics and Law
Department of Economics

Graduate School
Master of Science in Economics

New-Fisherian Transmission of a Monetary Policy Shock: a Swedish analysis

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Abstract

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In the aftermath of the Great Recession, central banks had to deal with stubborn low inflation. Therefore, as suggested by the mainstream literature, represented by the Taylor rule, they have reduced nominal interest rate until the Zero Lower Bound (ZLB). However, inflation remained low and stable. Then, monetary authorities turned to unconventional monetary policy, such as Forward Guidance; in spite of this, inflation is still below the target. In this framework, New-Fisherities state that inflation is low because of low nominal interest rates rather than despite of these; they sustain that almost zero nominal interest rate can pin down inflation. This research proves that, when the monetary policy shock is permanent, nominal interest rates and inflation follow the same path. Furthermore, the Swedish data evidences that after 2008 it is more likely to have a co-movement between interest rates and inflation, since, in this period, the estimated permanence of the shock is higher than before the crisis.

Keywords: New-Fisherianism; New Keynesian Model; Inflation; Nominal Interest Rate; Monetary Policy Shock; Bayesian Estimation.

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1. Introduction

Since the Great Recession, low inflation has been one of the main macroeconomic characteristics of many Western Countries. In particular, European Central Bank (ECB), Federal Reserves System (Fed) and the Swedish Riksbank have decided to lower interest rates in order to recover the system and to raise inflation (Amano et al., 2016). Indeed, conventional monetary policy, in a New Keynesian framework, follows the Taylor rule (see Taylor, 1993) which suggests reducing interest rate whenever inflation falls below the target in order to boost the economy and increase inflation, and to increase interest rate to reduce the spending and cool off the economy. However, in spite of the extremely low interest rates, inflation seems to be stable and very low. Similarly to what is happening nowadays in Europe and US, also Japan has experienced prolonged near-zero interest rates and deflation since 1990s (Aruoba et al., 2017). Therefore, this research is focused on the true relationship between nominal interest rate and inflation; it will study the effect of a monetary policy shock to the real economy in the modern macroeconomics models in order to evidence that central banks may control inflation in the wrong way. This long period of stubbornly low interest rate in the most of developed countries raises a question whether such low interest rate will be a permanent characteristic of the future economic activity. Laubach and Williams (2003) analyze a model they developed to measure highly persistent movements in the natural rate of interest[1] (see Laubach and Williams, 2003). According to this model, since the start of the Great Recession the natural rate of interest has fallen to, and remained at, historically very low levels near zero. This is due to a shifts in demographic, a slowdown trend productivity growth and global factor affecting the real interest rate. The new frame towards which modern economies are moving, featured by a long period of lower-than-before interest rates, both in the short and the long run, has been defined as the *New Normal*. John Williams, president of Federal Reserve Bank of San Francisco, argues (Williams et al., 2017):

> I know that for some the word normal conjures memories of the 90s, when interest rates were often above 4 percent. But like the pager, the Walkman, and the Macarena, were unlikely to see such rates return. Bottom line: In the

[1]Wicksell (1936) defines the natural interest rate as the interest rate which is neutral with respect to inflation. However, this definition refers to the long-run perspective of natural interest rate. Woodford (2003) refers to the fluctuations of natural interest rate in the short-run as the rate would prevail if prices were completely flexible

> new world of moderate economic growth, we all need to plan for relatively low rates for the foreseeable future.

This new landscape in modern economics entails important policy implications. Indeed, a lower average real interest rate in turn implies that episodes of monetary policy being constrained at the effective zero lower bound are likely to be more frequent and longer (Reifschneider and Williams, 2000). In such circumstances central banks have turned to unconventional monetary policy, namely *Negative interest on reserves*, *Quantitative Easing* and *Forward Guidance* (Joyce et al., 2012). Negative interest rate policy has been conducted by many central banks, e.g. ECB, BoJ and Riksbank. In accordance with this policy, central banks are today charging commercial banks for their reserves in order to stimulate the economy and to promote the commercial activity such as lending and borrowing (Arteta et al., 2018). Quantitative easing consists in large injection of liquidity in the economy through large-scale purchase of long-maturity assets by central bank (Kiley et al., 2018). The Forward guidance, sustained by Woodford, is the promise of keeping interest rates very low in order to affect future expectation regarding inflation and stimulate it today. Although, so far, these policies have brought the economy to experience several years of economic growth and falling unemployment rate, inflation seems to be unresponsive. Indeed, as stated by Williamson et al. (2016) both the ECB, Fed and Bank of Japan (BoJ) are still experiencing inflation below their targets, and they seem powerless to correct the problem. Further unconventional monetary policy actions do not seem to help. Though inflation is still below the target, since the improvement of output and unemployment, the Federal Reserve Board of Governors has started rising the policy rate from early 2016. Nowadays, FEDs economists are dealing with a recent debate concerning the effect of further raises of the short-term interest rate. In particular, recently, an alternative economic view - based on a positive relation between interest rates and inflation - has been proposed. Cochrane (2017) states that near to the Zero-lower-bound (ZLB) inflation could be still stable and, therefore, an increase in the interest rates could lead to a raise of inflation. This view is known as *New Fisherian Hypothesis* and it is based on the Fisher equation (see Taylor, 1993), a key concept also in mainstream macroeconomic literature. The *Fisher effect* can be stated and simplified as follows:

$$i_t = r_t + \mathbb{E}_t \pi_{t+1} \tag{1.1}$$

where i_t is nominal interest rate, r_t is the real rate and $\mathbb{E}_t \pi_{t+1}$ is the expected level of inflation at time *t+1*. The idea is that in the long run r_t is independent of economic activity - unemployment and spending for example - and so an increase in the nominal interest rate will have no effect on r and will be reflected only in a one-for-one increase in the inflation. This effect, named Fisher Effect, does not provide any information on the timing of rising inflation though. However, even if this effect is widely accepted just in the long-run by mainstream literature, Cochrane (2017) tests different New Keynesian models concluding that, near the ZLB, inflation positively reacts to the nominal interest rate also in the short-run.

The aim of this paper is to stress the unorthodox literature related to the New-Fisherianism and to compare it to the mainstream doctrine. Rupert and Šustek (2016) find that the transmission of a monetary policy shock to real economy depends on the calibration of the model and Garín et al. (2018) find out the presence of New-Fisherian effect in the New Keynesian textbook as inflation target increases permanently and prices are more flexible. Accordingly to the authors, I show that New-Fisherianism can arise also when the monetary policy shock is perceived as persistent and therefore the autoregressive coefficient of the Taylor shock is higher. Moreover, I fit Swedish data in the model and I estimate the autoregressive coefficient of the monetary policy shock, through Bayesian estimation, in order to check if it is large enough to cause co-movements between nominal interest rate and inflation after a monetary policy shock. The analysis shows that inflation and nominal interest rates, in Sweden, are more likely to move in the same direction after the crisis; indeed, if the sample employed, which goes from 1987 to 2017, is split into two samples, before and after the Great Recession, the persistence of the monetary policy shock is greater in the aftermath of the crisis. Therefore, this result has got important implications in monetary policy; indeed, it suggests that central bank may have inflation control wrong, and therefore, would be better increase slightly nominal interest rate in order to move up inflation.

This work is placed in a broader field of studies which analyzes the relationship between interest rates and inflation and the effectiveness of monetary policies at the ZLB. Sims (1992) and Eichenbaum (1992) find that nominal interest rates and inflation could move together after a policy shock, and they refer to this co-movement between them as the "price puzzle". However, even if most of the literature regarding New-Fisherianism is placed in the economics blogsphere, recently a new academic literature, sustained by important economists such as Bullard, Williamson and Cochrane, has been beginning to grow. Uribe (2017) and Aruoba et al. (2017) find econometric evidences, drawn from U.S and Japanese data, that a permanent increase in the nominal interest rate causes a fast adjustment of inflation to a permanently higher level and no output loss. Cochrane (2017) finds that conventional new Keynesian models predict that inflation is still stable at the ZLB and thus raising interest rates will increase inflation. Adding some frictions, namely money, backward looking Phillips curves and multiple equilibria, fails to escape this prediction. On the other hand, García-Schmidt and Woodford (2015) show that including complexity in the new Keynesian model and departure from the rational expectations - such as model accounting for Habits, rule-of-thumb agents and bounded rationality in general - eliminate the New-Fisherian predictions.

This paper, on the one hand, contributes to improve the wide literature about the transmission of the monetary policy shock to the economy and the relation between interest rates and inflation, on the other hand, it enriches the few studies regarding New-Fisherianism. Furthermore, as far as I know, this is the first research which estimates the persistence of the shock, in Sweden, in order to check co-movement between nominal interest rate and inflation; moreover, no article compares the parameters in two different periods, i.e. before and after 2008.

I believe that this study is of high importance for two reasons (i) The coexistence of near-zero interest rates and low inflation shows the stability of the latter also at the zero lower bound and so it opens to new consideration regarding the transmission of monetary shock to the economy (ii) the New-Fisherian Hypothesis argues that conventional central banking wisdom has inflation control wrong, so studying weakness and strengths of this new "school of thought" could lead to important results with implication in policy analysis.

The reminder of this work is organized as follows. In Chapter 2, the New Keynesian model is presented along with the mechanisms which drive the monetary policy. In Chapter 3, the New-Fisherian Hypothesis is introduced. Moreover, the failures and the ambiguities of the New Keynesian model are analyzed. Finally, Chapter 4 is devoted to the simulation of Impulse Response functions to a monetary policy shock and the estimation of the persistence of the Taylor shock in Sweden. Finally, in chapter 5 the conclusions are drawn.

2. New Keynesian model

The debate just introduced can be better understood within the framework of a small New-Keynesian (NK) models - a dynamic stochastic general equilibrium model (DSGE). This class of models has at its core in some version of the Real Business Cycle model[1] (RBC) (see Prescott, 1986). Likewise RBC models, they are based on some important assumptions such as infinitely-lived representative household who seeks to maximize the utility from consumption and leisure subject to an intertemporal budget constraint, and the presence of a large number of firms, with access to an identical technology, subject to exogenous random shocks. Both The New Keynesian and the Real Business Cycle explain how business cycle can arise given an exogenous technology shock, but the NK models extend this framework in order to formulate monetary policy. Therefore, they introduce a new idea behind the AS short-run[2]; indeed, it is considered to be upward-sloping due to rigidity in the market created by *Monopolistic competition* - each firm has monopolistic power in the market she operates - and *price rigidity*, namely sticky price/wage, since firms are subject to some constraints on the frequency with which they can adjust the prices of the goods and services they sell. This causes a change of perspective in the role of the monetary policy in the short run: changes in short term nominal interest rates are not matched by one-to-one changes in expected inflation; therefore it affects both real and nominal variables. This approach of the New Keynesian economists is also defined as *short run non-neutrality of monetary policy.* Wage and price stickiness, and the other market failures present in New Keynesian models imply that the economy may fail to attain full employment. Therefore, New Keynesians argue that macroeconomic stabilisation is achieved by Government (fiscal policy) or by central bank (monetary policy) (Galí, 2015). In particular, the central bank uses short-term interest rates as instrument to influence output and inflation through the transmission via the aggregate demand to them.

[1]It is a class of model in which the fluctuation of the output is driven by real shocks rather than nominal ones.

[2]It is the Aggregate supply curve which describes, for each level of prices, the amount of output which is supplied by the firms

2.1 The model

In this section, I present the New Keynesian model and its main features. I introduce the maximization/minimization problem faced by both the households and the firms. Moreover, I provide the Taylor rule and how a monetary policy shock propagates to the real economy. Following Galí (2015), NK models are characterized by three main equations. The first equation is the Dynamic IS curve (DIS). The DIS is derived from the utility maximization problem faced by the households. The second fundamental equation is the New Keynesian Phillips curve which describes the inflation behaviour. Furthermore, along with these two main equations, is the Taylor rule which is used by central banks in order to control both output and inflation.

2.1.1 Households

In this economy, the representative infinity-lived household maximizes his expected life-utility at time t=0. Thus:

$$\max_{C_t, N_t} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t, N_t) \tag{2.1}$$

where C_t represents the consumption index given by:

$$C_t = \left(\int_0^1 C_t(i)^{1-\frac{1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \tag{2.2}$$

With $C_t(i)$ representing quantity of good i consumed by the agent and ϵ is the constant elasticity of substitution[3]. Moreover, We assume that a continuum good represented by the interval [0,1] exists.

The agent maximizes his utility subject to the following budget constraint:

$$\int_0^1 P_t(i) C_t(i) di + Q_t B_t \leq B_{t-1} + W_t N_t + T_t \tag{2.3}$$

where $P_t(i)$ is the price good i at time t, B_t and B_{t-1} are Bonds respectively at time t and t-1, Q_t is the price of Bond at time t, W_t and N_t are wage and hours of work at time t and T_t is lump-sum taxes at time t. Moreover, along with the sequence of period budget

[3]The higher is ϵ the lower is the the market power of producers.

constraints, the No-Ponzi game condition[4] holds. In addition to the utility maximization problem, the agent, in the New Keynesian model, seeks to maximize the allocation of its consumption expenditure among the different goods[5]. The solution of this problem leads to the consumption demand:

$$C_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} C_t. \tag{2.4}$$

for all $i \in [0,1]$. P_t is the aggregate Price index. Therefore, if the period utility takes the following form[6]:

$$U(C_t, N_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \tag{2.5}$$

where β is the discount factor, σ is coefficient of relative risk aversion and φ is the inverse of Frish elasticity, i.e. the elasticity of work with respect to wage. We can rewrite the utility maximization problem of the agent as:

$$\max_{C_t, N_t, B_t} \quad \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} - \Lambda(P_t C_t + Q_t B_t \leq B_{t-1} + W_t N_t + T_t) \tag{2.6}$$

The first order conditions derived from the Lagrangian are the following:

$$\frac{\delta \mathcal{L}}{\delta C_t} = 0 \Rightarrow C_t^{-\sigma} = \Lambda_t P_t$$

$$\frac{\delta \mathcal{L}}{\delta N_t} = 0 \Rightarrow N_t^{\varphi} = \Lambda_t W_t \tag{2.7}$$

$$\frac{\delta \mathcal{L}}{\delta B_t} = 0 \Rightarrow \beta \frac{\Lambda_{t+1}}{\Lambda_t} = Q_t$$

By solving forward the system, we can recover both the Labour supply equation and the Euler Equation:

$$\frac{W_t}{P_t} = N_t^{\varphi} C_t^{\sigma} \tag{2.8}$$

[4]The No-Ponzi Game condition is a solvency condition on government bonds: $lim_{T \to \infty B_t \geq 0}$.

[5]This means that the agent tries to maximize C_t with respect to the total expenditure $\int_0^1 P_t(i) C_t(i) di$.

[6]All the regularity conditions hold and $\delta U / \delta C_t > 0$, $\delta U / \delta N_t < 0$, $\delta U / \delta C_t^2 < 0$ and $\delta U / \delta N_t^2 > 0$.

$$\mathbb{E}\left[\beta\left(\frac{C_{t+1}}{C_t}\right)^{1-\sigma}\frac{1}{\pi_{t+1}}\right] = Q_t \tag{2.9}$$

where C_{t+1} and π_{t+1} are respectively expected consumption and expected inflation at time t+1. The (2.9) represents the allocation consumption between different periods by acquiring bonds at price Q_t.

2.1.2 Firms

Besides the maximization problem of the household, in this section, I discuss what is the optimal behaviour of the firms.

We assume a continuum of firms, indexed by $i \in [0, 1]$. The production function of each firm - which produces a differentiated goods - is the following:

$$Y_t(i) = A_t N_t(i)^{1-\alpha} \tag{2.10}$$

where A_t is the identical technology among firms. Moreover, each firm faces an iseolastic demand schedule:

$$C_t(i) = \left(\frac{P_t(i)}{P_t}\right)^{-\epsilon} C_t \tag{2.11}$$

Thus, we can derive the optimal firms behavior from the following maximization problem:

$$\begin{aligned} \max_{P_t(i),N_t(i)} \quad & P_t(i)Y_t(i) - W_t N_t(i) \\ s.t. \quad & Y_t(i) = Y_t\left(\frac{P_t}{P_t}\right)^{-\epsilon} = A_t N_t(i)^{1-\alpha} \end{aligned} \tag{2.12}$$

The following maximization problem is affected by a new problem faced by firms, i.e. sticky prices. Indeed, in the New Keynesian model prices are staggered, and they are set *á la Calvo*; in each period each firm faces a probability θ to not succeed to adapt new prices[7]. Therefore, $1 - \theta$ represents the number of firms which adjust their prices[8] (see Calvo, 1983).

[7] The probability of adjusting is independent of when the firm last changed its price.

[8] $\frac{1}{1-\theta}$ is the average duration of a price contract when allowed to change expectations about future price changes become important.

Then, the aggregate price is:

$$P_t = \left(\int_0^1 P_t(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}} \tag{2.13}$$

since price level is adjusted *á la Calvo*, it will be fraction $1-\theta$ re-optimizing firms and θ non re-optimizing firm with $\theta \in [0,1]$. Therefore, the aggregate mechanism becomes:

$$P_t = \left(\theta \int_{S(t)} P_t(i)^{1-\epsilon} dS(t) + (1-\theta) P_t^{*(1-\epsilon)} \right)^{\frac{1}{1-\epsilon}} \tag{2.14}$$

where $P_t^{*(1-\epsilon)}$ is the price set by re-optimizing firms and $S(t)$ is the set of non re-optimizing firms which set a price $P_t = P_{t-1}$.

Since the distribution of prices among non-resetting firms corresponds to prices prevailing in the previous period we have that:

$$P_t = (\theta P_{t-1}^{1-\epsilon} + (1-\theta) P_t^{*1-\epsilon})^{\frac{1}{1-\epsilon}} \tag{2.15}$$

then dividing both sides by $P_{t-1}^{1-\epsilon}$ we can finally state that the aggregate price dynamics are described by the following equation:

$$\Pi_t^{1-\epsilon} = \theta + (1-\theta) \left(\frac{P_t^*}{P_{t-1}} \right)^{1-\epsilon} \tag{2.16}$$

where $\Pi_t^{1-\epsilon} = \frac{P_t}{P_{t-1}}$ is the gross inflation rate between t-1 and t. Therefore, the (2.16) states that inflation arises from the re-optimizing problem which is faced by firms; this is due to the fact that at any given period each firm could choose a price which differs from the average price in the previous period (Galí, 2015). Furthermore, a firm which wants to maximize its profit, would choose P_t^* that maximizes the following problem:

$$\begin{aligned} \max_{P_t^*} \quad & \sum_{k=0}^{\infty} \theta^k \mathbb{E}_t \{ Q_{t,t+k} \underbrace{(P_t^* Y_{t+k|t}}_{Revenues} - \underbrace{\Psi_{t+k}(Y_{t+k|t}))}_{Costs} \\ s.t. \quad & Y_{t+k|t} = \left(\frac{P_T^*}{P_{t+k}} \right)^{-\epsilon} C_{t+k} \end{aligned} \tag{2.17}$$

where $Q_{t,t+k} = \beta^k \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+k}}$; so the firm will discount future profits by the gross nominal interest rate between t and t+k and $\Psi_{t+k}(.)$ is the cost function. Moreover, firms face a dualistic problem; on the one hand, they try to maximize their revenues, on the other, they want to minimize their costs. Therefore, they minimize the amount of labour in order to minimize the cost. The minimization problem can be stated as:

$$\begin{aligned} \min_{N_t(i)} \quad & \frac{W_t}{P_t} N_t(i) \\ s.t. \quad & Y_t(i) = A_t N_t(i)^{1-\alpha} \end{aligned} \tag{2.18}$$

Thus, the we can rewrite the minimization problem through the Lagrangian function:

$$\min_{N_t(i)} \quad \frac{W_t}{P_t} N_t(i) - MC_t(i)(Y_t(i) - A_t N_t(i)^{1-\alpha}) \tag{2.19}$$

where the Lagrangian multiplier $MC_t = \frac{W_t/P_t}{A_t}$ measures the real marginal cost faced by each firm.

2.1.3 Equilibrium conditions

In this section, I illustrate the equilibrium conditions. The market clearing condition serves the purpose to illustrate the supply-demand equilibrium. The clearing for the good market is:

$$Y_t(i) = C_t(i) \tag{2.20}$$

from which we can get:

$$Y_t = C_t \tag{2.21}$$

which represents the Aggregate output demand. Moreover, we have the labor market clearing which is:

$$N_t = \int_0^1 N_t(i) di \tag{2.22}$$

where if we use (2.10) we find that:

$$N_t = \left(\frac{Y_t(i)}{A_t}\right)^{\frac{1}{1-\alpha}} \int_0^1 \left(\frac{P_t(i)}{P_t}\right)^{-\frac{\epsilon}{1-\alpha}} di \tag{2.23}$$

2.1.4 Log-linearized model

Here, I introduce a different formalization of the previous results. Indeed, all the equation we have found so far are non-linear. Therefore, in order to avoid very difficult computations to solve the simultaneous system of equation, I will turn those equations in linear ones. In order to do that, I apply a very well-known technique in macroeconomics field which is called Log-linearization[9]. Such process allows us to move into a linear field; indeed, this technique consists in expressing the system of non-linear simultaneous equations into an equivalent which is linear in terms of log-deviation from the steady state value (Zietz, 2006). The new system of log-linear equations is the following:

$$\widehat{w}_t - \widehat{p}_t = \varphi \widehat{n}_t + \sigma \widehat{c}_t \tag{2.24}$$

$$\widehat{c}_t = \mathbb{E}_t \widehat{c}_{t+1} - \frac{1}{\sigma}(\widehat{i}_t - \mathbb{E}_t \widehat{\pi}_{t+1}) \tag{2.25}$$

$$\widehat{\pi}_t = (1-\theta)(\widehat{p}_t^* - \widehat{p}_{t-1}) \tag{2.26}$$

$$\sum_{k=0}^{\infty} (\theta\beta)^k (\widehat{p}_t^* - \widehat{p}_{t-1}) = \sum_{k=0}^{\infty} (\theta\beta)^k \mathbb{E}_t[(\widehat{mc}_{t+k|t} + (\widehat{p}_t^* - \widehat{p}_{t-1}))] \tag{2.27}$$

$$\widehat{mc}_t = \widehat{w}_t - \widehat{p}_t - \widehat{a}_t + \alpha \widehat{n}_t \tag{2.28}$$

$$\widehat{p}_t = (1-\theta)\widehat{p}_t^* + \theta \widehat{p}_{t-1} \tag{2.29}$$

$$\widehat{c}_t = \widehat{y}_t \tag{2.30}$$

$$\widehat{n}_t = \frac{1}{1-\alpha}(\widehat{y}_t - \widehat{a}_t) \tag{2.31}$$

where the (2.24) equation represents the Labour Supply, the (2.25) is the Euler Equation, the (2.26) is the Inflation Dynamics, the (2.27) describes the Price setting mechanisms, the (2.28) is the Firms Cost Minimization, the (2.29) represents the Price Dynamics,

[9] see Appendix A

then there is the (2.30) which is Goods Market Clearing and finally the (2.31) is the Labor Market Clearing.

2.1.5 Reduced form model

In order to get the first fundamental equations of our model we can plug the (2.30) in the (2.25) in order to obtain the Dynamic IS curve:

$$\widehat{y}_t = \mathbb{E}\{\widehat{y}_{t+1}\} - \frac{1}{\sigma}(i_t - \mathbb{E}\{\widehat{\pi}_{t+1}\}) \tag{2.32}$$

with $\widehat{y}_t$ and $\mathbb{E}\{\widehat{y}_{t+1}\}$ denoting the log-deviation of output from the steady state at t and t+1. Following the so called Neo-Wicksellian framework (Woodford, 2001), we can rewrite the (2.32) in terms of output gap and enhance the DIS relation accounting for the natural rate of interest, thus:

$$\tilde{y}_t = \mathbb{E}\{\tilde{y}_{t+1}\} - \frac{1}{\sigma}(i_t - \mathbb{E}\{\widehat{\pi}_{t+1}\} - r_t^n) \tag{2.33}$$

where $\tilde{y}_t = \widehat{y}_t - y_t^F = \tilde{y}_t - \psi_{ya}^n a_t$ is difference between actual output and the output which would prevail if prices were flexible, $\psi = \left(\frac{1+\varphi}{\sigma(1-\alpha)+\varphi+\alpha}\right)$, r_t^n is the natural interest rate and $a_t = \rho_a a_{t-1} + \eta_{a,t}$ is the technology productivity shock which follows an AR(1). Therefore, the DIS relates current output gap to its future one-step prediction and the real interest rate, as a result of the intertemporal optimization of the consumers. The second fundamental equation is the New Keynesian Phillips Curve (NKPC).

$$\widehat{\pi}_t = \beta\mathbb{E}\{\widehat{\pi}_{t+1}\} + k\tilde{y}_t \tag{2.34}$$

where $\widehat{\pi}_t$ and $\mathbb{E}\{\widehat{\pi}_{t+1}\}$ are still the log-deviation of inflation from the steady state at time t and t+1, $\tilde{y}_t$ is the log-linearized version of the output gap and $k = \frac{(1-\theta)(1-\beta\theta)(\sigma(1-\alpha))+\varphi+\alpha}{\theta(1-\alpha-\alpha\epsilon)}$ represents the degree of price rigidity. The prices stickiness derived from the forward-looking behaviour of price setting of the firms. The idea is that, following the Calvo pricing mechanism, each firm faces with some probability at any given period the possibility to reset prices with the necessity to predict future marginal cost. The NKPC links the price level at time t with the expected one-step-ahead inflation and the present level of real economy performance. Therefore, inflation is positively correlated with future output, and past inflation does not matter given that inflation results from price setting decisions which depend on current and expected marginal costs. The DIS and the NKPC represent the non-policy part of the New Keynesian model.

Finally, in order to close the baseline model, I present an equation which rules how the monetary policy must be conducted by central banks. I assume that policy makers manage nominal interest rate in order to respond to change in inflation in accordance with such a feedback rule:

$$i_t = \phi_\pi \widehat{\pi}_t + \phi_y \tilde{y}_t + \theta_{i,t} \tag{2.35}$$

where both $\widehat{\pi}_t$ and $\tilde{y}_t$ are deviations of current levels from the respective steady-state levels and compose the systematic part of the equation, and $\theta_{i,t} = \rho_i \theta_{i,t-1} + \eta_{i,t}$ is an exogenous monetary policy shock which follows an AR(1) process. Such feedback rule has been proposed by Taylor in 1993 and all the mainstream macroeconomic policy analysis still leans on equation (2.35).

2.2 Taylor Rule

The Taylor rule has attracted the attention of the most central banks which have been using this rule and its extensions in order to modeling their monetary policy. The Taylor rule bears the name of the economist John Taylor who first modeled such interest rate feedback rule in order to design the monetary policy. Taylor (1993) proposes the following feedback rule:

$$i_t = i^* + \phi_\pi(\pi_t - \bar{\pi}) + \phi_y(\widehat{y}_t - \bar{y}) \tag{2.36}$$

where $i^* = -log\beta$, $(\pi_t - \bar{\pi})$ is the difference between actual inflation and target inflation set by policy maker and $(\widehat{y}_t - \bar{y})$ represents the difference between the present level of real economy performance and the potential output. ϕ_π and ϕ_y are non-negative coefficient which represent the degree of concern to each variable, namely inflation and output, and they reveal the target which is pursuing central banks, so a central bank which is more devoted to fluctuation in inflation would set $\phi_\pi > \phi_y$, instead if policy authority prefers keeping the output gap as low as possible they would set $\phi_y > \phi_\pi$. One of the first problems of the Taylor rule is that it can be affected by indeterminacy problem, indeed it could lead to indeterminacy of the rational-expectations equilibrium price level. As stated by Woodford (2001), considering the question in the context of the "neo-Wicksellian" model, i.e. including the natural interest rate in the (2.33), we can solve the system in order to find the rule which eliminates indeterminacy. Indeed, following Woodford (2001), we can insert (2.35) in (2.33) in order to remove i, and we can rewrite the system in matrix notation as follows:

$$\mathbb{E}z_{t+1} = Bz_t + e_t \tag{2.37}$$

where B is the vector containing π_t and y_t and e_t is a vector of exogenous terms. It follows that the system has a unique and stationary solution if and only if both eigenvalues of the matrix B lie outside the unit circle: This condition is verified only if:

$$\phi_\pi + \frac{1-\beta}{k}\phi_y > 1 \tag{2.38}$$

This rule is also known as Taylor Principle and it states that nominal interest rate has to increase more than 1-to-1 with respect to discrepancy between target inflation and observed inflation, thus $\phi_\pi > 1$. Therefore, the Taylor rule represents exactly the New Keynesian view regarding the monetary policy; indeed, it states that nominal interest rates need to be low whenever inflation falls below inflation target, and to increase whenever inflation is higher than inflation objective. During the Great Recession, after the housing bubble burst, output and inflation have fallen dramatically below the target, so Fed and ECB, in order to recover the system, have set nominal interest rate very low and it almost hit the ZLB - following exactly the Taylor rule. Interest rates have been about zero for almost seven years. During those seven years, Fed, ECB and Sveriges Riksbank, since interest rates were stuck at the ZLB, and in some cases negative, have turned to unconventional monetary policies, such as Forward Guidance and Quantitative Easing, but inflation did not increase. Since 2015, Fed, even if inflation was not recovered yet, has been increasing nominal interest rate departing from the Taylor rule. The behaviour of the Fed makes room to a new debate regarding the effect of increasing interest rate when inflation is still below the target.

2.3 Monetary Policy

One of the main features which has been added by New Keynesian model to Real Business cycle model is the non-neutrality of money. Indeed, after several years of focus on the non-monetary factors which drive the business cycle many empirical papers, such as Romer (1986) or Bernanke et al. (1997), reveal the real non-neutrality of money in the short-run. The non-neutrality of money in the New Keynesian model is driven by some frictions, such as price rigidity, which makes changes in nominal variables effective also in the real counterparts. Therefore, money in this model affects real economy such as traditional Keynesian IS/LM model does (Clarida et al., 1999). What is new in the NK models is that, since they are micro-founded, they are derived from the dynamic optimization problem of firms and households. Therefore, the Dynamic IS would provide not just a relation between macroeconomic aggregate and actual monetary policy but even a link between aggregate and expected monetary policy. Indeed, looking at the model, actual output depends positively on expected output and negative on nominal interest rate which is used by central bank as instruments for monetary policy. The inverse relation between nominal interest rate and output reflects the effect of the intertemporal substitution of consumption. Therefore, a positive monetary policy shock, in accordance with New Keynesian model, which leads to an increase in nominal interest rate and therefore to a hike of the real interest rate would reduce the output through the Dynamic IS curve. This is due to the fact that agents postpone their consumption and the output will be contracted.

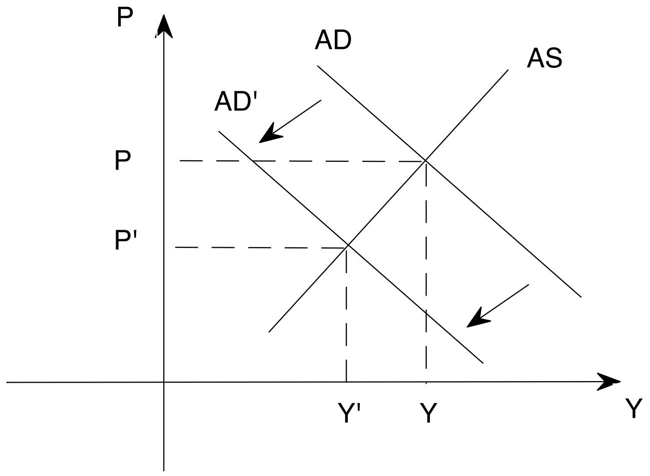

FIGURE 2.1: AD-AS dynamic: This figure shows the effect of a positive monetary policy shock in the New Keynesian framework; a positive shock, push down aggregate demand and, therefore, it reduces both prices and output.

As visible in Figure 2.1, an increase in nominal interest rate will push down the AD curve and will lead to less output. Moreover, since output decreases after a positive monetary policy shock, through the New Keynesian Phillips curve, also the level of price would decrease along with output. Therefore, the mechanism will be following:

$$\tilde{y}_t \downarrow = \mathbb{E}\{\tilde{y}_{t+1}\} - \frac{1}{\sigma}(i_t \uparrow - \mathbb{E}\{\widehat{\pi}_{t+1}\} - r_t^n) \implies \widehat{\pi}_t \downarrow = \beta\mathbb{E}\{\widehat{\pi}_{t+1}\} + k\tilde{y}_t \downarrow$$

Therefore, we have just provided the New Keynesian relation between nominal interest rate, output and inflation. Moreover, if there is no nominal rigidities, we can solve the (2.33) forward in order to get:

$$\tilde{y}_t = -\frac{1}{\sigma}\sum_{k=0}^{\infty}(r_{t+k} - r^n_{t+k}) \tag{2.39}$$

where $r_t = i_t - \mathbb{E}_t\{\pi_{t+1}\}$ is the real interest rate. Thus, current output gap is a collection of present and expected fluctuation of the real interest rate gap. Therefore, a central bank which wants to pursue a zero output gap, needs to reduce natural interest rate gap to zero, i.e. equating real interest rate to natural interest rate. Furthermore, as suggested by Blanchard and Galí (2007), the so called "divine coincidence" implies that there is no trade off between targeting a null output gap or preferring to stabilize inflation. In this context of optimal monetary policy, as argued by Galí (2015), with no nominal rigidities[10] and allowing for correction for the monopolistic power distortion, the flexible price output equates natural output. Therefore, thanks to this simplification, central banks try to reach a situation in which output is equal to output at flexible price - second best - instead of to natural output - first best. Therefore, in this scenario, pursuing a zero output gap scenario is equal to pursuing $r_t = \hat{r}^n_t$.
In this framework, if central banks raise nominal interest rate, they bring negative effect on both output gap and inflation, through a reduction of real interest rate. Relating to the initial debate, a standard NK model would suggest to not increase nominal interest rate today, since it would result in a contractionary monetary policy which would slow down the moderate post-recession economic growth and lower inflation, which is still below the target. Although such a discussion, Fed has been hiking nominal interest rate even if inflation is still below the target, and ECB is planning to do the same in the next future. This new scenario provides additional food of thoughts for a new debate regarding the effect of increasing nominal interest rate when inflation is still below the target and after several years of prolonged Zero interest rate policy. In particular, New-Fisherities claim that increasing nominal interest rate is needed to restore expectation and confidence about future inflation and, therefore, to raise inflation today.

[10] Galí (2015) assumes that nominal rigidities die out at an infinite horizon.

3. New-Fisherian Hypothesis

The history of Japan economy since 1990s and US economy in the aftermath of the Great Recession are very similar. Indeed, both of the economies experienced an unstable boom which, once burst, has led to several years of deflation on the Asian island and almost 10 years of deep stagnation in the US economy. On the one hand, Japan has experienced an enormous bubble in asset prices and in property values; indeed, the value of the Nikkei 225 stock market index[1] rose from 6,000 to 40,000 in less than 10 years while the property values doubled. On the other hand, the Home Prices for US increase 85% between 1997 and 2006[2] and the Down Jones Industrial Index almost doubled between 2002-2005. Then, in both of them - Japan and US - the bubble burst and it has led to several years of deflationary tendencies. Therefore, in order to recover the system, Japan and US have lowered the policy interest rate near to zero; however, this solution of Zero Interest Rate policy (ZIRP) failed to simulate the economy. Since conventional monetary policy failed to reach the adequate results, Japan and US have turned to unconventional monetary policies, such as Quantitative Easing - the large-scale purchase of long-maturity assets by a central bank - and Forward guidance (Ueda, 2012). The latter consists in promises by the central bank to maintain nominal interest rate low; the idea is to manage expectation about the future path of the policy rate in order to affect current macroeconomic outcomes (Galí et al., 2018). The Forward guidance plays a fundamental role in the New Keynesian model, indeed, thanks to the rational nature of the model, higher expected real income or inflation in the future bring to incentives for higher expenditure today; the idea is that if central banks would behave as conventional monetary policy then nominal interest rate would increase and it would lower expenditure today while if central banks promise to keep interest rate low for a given period, then, increase the expected real income and inflation producing an increase in real expenditure and inflation today (Woodford et al., 2012). However, today, after several years of ZIRP and unconventional monetary policy, inflation is below the target. Along with Japan and US, also Europe and Scandinavian countries have experienced long period of almost zero nominal interest rate and stubborn low inflation.

[1] Is a stock market index for the Tokyo Stock Exchange (TSE).

[2] Bank for International Settlements, Real Residential Property Prices for United States [QUSR628BIS], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/QUSR628BIS, April 6, 2018.

Although Sveriges Riksbank has even cut nominal interest rate to -0.5 and large purchase of government bonds has been carried out, inflation has shown poorer response than they expected; indeed, inflation rate is still below the target set to 2% (Monetary Policy Report, February 2018). Therefore, the ineffectiveness of conventional and unconventional monetary policies, along with the decision of Fed to hike nominal interest rate, is questioning whether the transmission of monetary policy to real economy is not well understood by mainstream literature. The Federal Reserve Board of Governors has started rising the policy rate from early 2016. Nowadays, FEDs economists are dealing with a recent debate concerning the effect of further raises of the short-term interest rate. Williamson et al. (2015) state that "normalization" - a macroeconomic equilibrium that includes higher nominal interest rate - is required to bring the US economy to perform well. In accordance with this view, New-Fisherites argue that mainstream literature and conventional monetary policy fail to predict the real relationship between inflation and short nominal interest rate; they sustain that increase (reduce) nominal interest rate would lead to an increase (reduction) inflation (Williamson et al., 2018). Many authors, such as Cochrane (2017), Williamson et al. (2016) or Bullard (2010), sustain that the true relation between inflation and nominal interest rate is well described by the Fisher equation, here reported for simplicity:

$$i_t = r_t + \mathbb{E}_t \pi_{t+1} \tag{3.1}$$

where i_t is the nominal interest rate at time t, r_t is the real interest rate at time t and $\mathbb{E}_t \pi_{t+1}$ is the expected inflation at time t+1. Therefore, the Fisher equation provides a positive relation between expected inflation and short nominal interest rate. The relation established by (3.1) is widely accepted in the long run. Indeed, to simplify, if in the short run central bank monetary policy affects real interest rate r_t and consequently on real economic activity, in the long run, real interest rate is independent of monetary policy and therefore (3.1) encodes a long-run positive relation between nominal rates and expected inflation. According to this view, it is unlikely that forward guidance will achieve the desired result; indeed, if central bank promises to keep interest rate very low would decrease inflation rather than increasing it, this is due to the fact that in the long run low interest rates pin down expected inflation. Therefore, in the long run, Fisher equation is widely accepted by the most economists and the mainstream literature. Moreover, the history of Japan, US, ECB and many other countries - namely Scandinavian countries and UK - are empirical evidences in support of New-Fisherian Hypothesis. To clarify this concept, I have plot average inflation rate against nominal interest rate across countries and the result is shown in Figure 3.1.

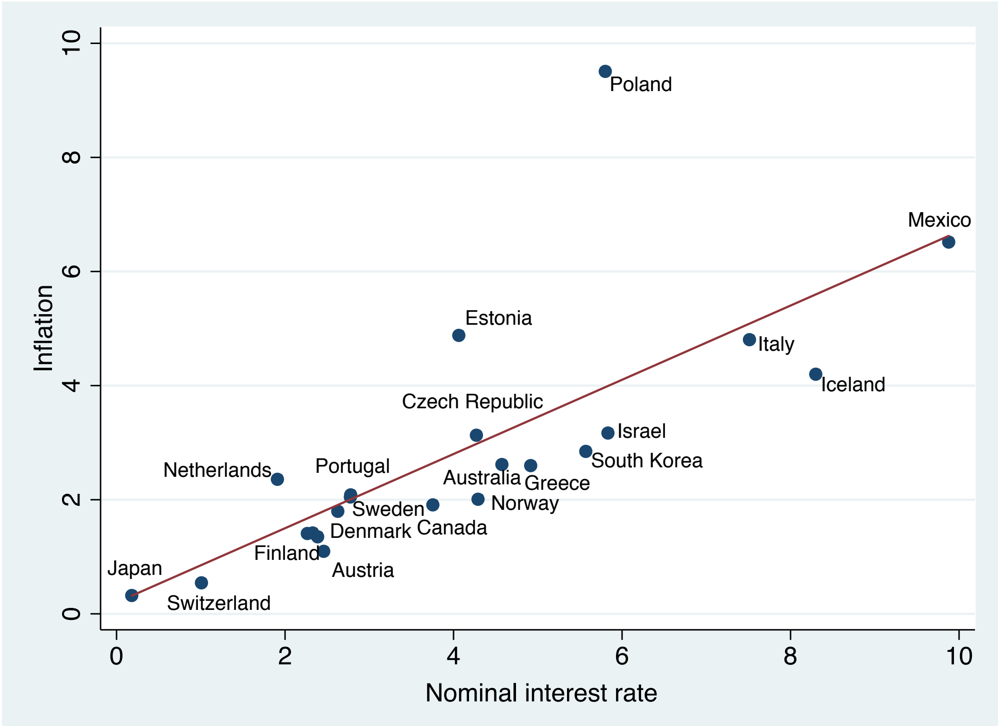

FIGURE 3.1: In the figure are plot the mean of both nominal interest rate and inflation in the period between 1995-2017 of 20 countries members of OECD. All the data have been retrieved from FRED, Federal Reserve Bank of St. Louis.

It is possible to notice that countries where nominal interest rates have been low for long period are more likely to suffer from permanent low inflation, and vice versa.

3.1 New-Fisherianism in the New-Keynesian model

The New Keynesian models - which, along with their features, have been largely discussed - are considered the core of modern monetary policy. The baseline version of that model is the workhorse of modern macroeconomics theory and it is used for both applied economics and forecasting (see Smets and Wouters, 2004). Indeed, this model provides the guideline of modern macroeconomics theory and the way in which a monetary policy shock - or Taylor rule shock - propagates to real economy. As demonstrated, given the frictions which characterized the model, central banks, controlling nominal interest rate, can control real rate of interest. Therefore, an increase in nominal interest rate would lead to higher real interest rate which - through the mechanism of the Dynamic IS and the New Keynesian Phillips curve - reduces both output and inflation. However, Rupert and Šustek (2016) prove that in a baseline New Keynesian model the response to a monetary policy shock depends on parametrization. Indeed, Rupert and Šustek (2016) and Cochrane (2017) evidence that when the persistence of the monetary policy shock becomes higher than it is more likely that inflation and nominal interest rate follow the same path. Following Cochrane (2017), it is possible to prove this statement. Consider the baseline New Keynesian model - introduced in the previous chapter - with a central bank mono-mandate[3]:

$$\tilde{y}_t = \mathbb{E}\{\tilde{y}_{t+1}\} - \frac{1}{\sigma}(i_t - \mathbb{E}\{\widehat{\pi}_{t+1}\} - r_t^n) \tag{3.2}$$

$$\widehat{\pi}_t = \beta\mathbb{E}\{\widehat{\pi}_{t+1}\} + k\tilde{y}_t \tag{3.3}$$

$$i_t = \phi_\pi \pi_t + \theta_{i,t} \tag{3.4}$$

$$\theta_t = \rho_i \theta_{i,t-1} + \eta_{i,t} \tag{3.5}$$

where for simplicity $r_t^n = 0$. Using lag-operator techniques to solve the inflation path analytically, we find[4]:

$$\pi_t = -\frac{\sigma k}{1 + \sigma k \phi_\pi} \left(\frac{1}{(1 - \lambda_1 \rho)(1 - \lambda_2 \rho)} \right) \theta_{i,t} \tag{3.6}$$

where λ_1 and λ_2 are the unit roots of the lag operator and both are $\lambda_{1,2} < 1$. Therefore, a positive monetary policy shock would lead to negative inflation. Now, we can plug (3.6) into the feedback rule (3.5) in order to check how inflation responds to a monetary policy shock, thus:

$$i_t = \left[1 - \underbrace{\frac{\phi_\pi \sigma k}{1 + \sigma k \phi_\pi}}_{a} \left(\underbrace{\frac{1}{(1 - \lambda_1 \rho)(1 - \lambda_2 \rho)}}_{b} \right) \right] \theta_{i,t} \tag{3.7}$$

where $a < 1$, but the value of b depends on ρ; indeed, since $\lambda_{1,2} < 1$ if ρ increases then the denominator decreases and b increases. Therefore, if ρ is large enough to get $a * b > 1$ then a positive monetary policy shock will have negative impact also on nominal interest rate. This means that if $\rho > c$ inflation and nominal interest rate can move in the same direction, as stated by New-Fisherities.

[3] It has just an inflation target.
[4] Derivation shown in Appendix C.

3.2 Peril of Taylor Rule

In support of this new school of thought, many economists assert that behaving accordingly to the Taylor rule could lead some problem, mostly at the ZLB. Indeed, although the Taylor rule is active since many years and most of the central banks employ such relation in order to govern the monetary policy, many authors such as Benhabib et al. (2001), Bullard (2010), Williams et al. (2017) and Cochrane (2017) find some issues which may arise using an active rule[5] such this. Indeed, Benhabib et al. (2001) show that an active Taylor rule could lead to multiple steady state equilibria; in particular, at the Zero Lower Bound. They state that an active Taylor rule which accounts for the ZLB, has two equilibria; (i) a good equilibrium in which central bank reaches inflation target and (ii) a bad equilibrium where the nominal interest rate is constrained at the Zero Lower bound and the economy is affected by stubborn deflation spiral. Following the literature proposed by Benhabib et al. (2001), Bullard (2010) finds in Japan an empirical evidence of the worst scenario which can be placed by an active Taylor rule. Indeed, the Japanese case shows that in the long run a persistent ZIRP can pin down inflation. Therefore, Bullard (2010) states that promising to keep nominal interest rate low for long time, on the one hand, can move up inflation and expected inflation since agents would know that low interest rate will result in higher inflation tomorrow and, therefore, they would consume more today, so through the NKPC present inflation will raise, on the other hand, in the long run, expected inflation and nominal interest rate are linked by the Fisher equation and, therefore, almost zero nominal interest rate can pin down expected inflation rather than increasing it. He concludes that forward guidance and strong commitment could have negative results. I will follow Williams et al. (2017) in order to explain where the Taylor rule can fail. The model, proposed by Williamson, is a baseline New Keynesian model with just the DIS equation:

$$\tilde{y}_t = \mathbb{E}\{\tilde{y}_{t+1}\} - \frac{1}{\sigma}(i_t - \mathbb{E}\{\widehat{\pi}_{t+1}\} - r_t^n) \tag{3.8}$$

and a New Keynesian Phillips Curve:

$$\pi = k\tilde{y}_t + \beta\mathbb{E}_t\{\pi_{t+1}\} \tag{3.9}$$

where, for simplicity, it is possible to set $\beta = 0$ and therefore:

$$\pi = k\tilde{y}_t \tag{3.10}$$

[5]Active rule means that central banks respond more than 1-to-1 to inflation gap $\phi_\pi > 1$.

which will not modify the results but it will just make easier the computations. Along with these two equations, I assume that central banks follow a Taylor rule which accounts for ZLB and targets just inflation:

$$i_t = \max[0, r_t^n + \pi^* + \phi_\pi(\pi_t - \pi^*)] \tag{3.11}$$

where π^* is the inflation target chosen by central bank. From (3.8), (3.10) and (3.11) we can recover the inflation path:

$$\pi_{t+1} = \max[\frac{\sigma}{k+\sigma}\pi_t - \frac{kr_t^n}{k+\sigma}, \frac{(1-\phi_\pi)k}{k+\sigma}\pi^* + \frac{\phi_\pi k + \sigma}{k+\sigma}\pi_t] \tag{3.12}$$

In Figure 3.2, we represent the inflation path under an active Taylor rule.

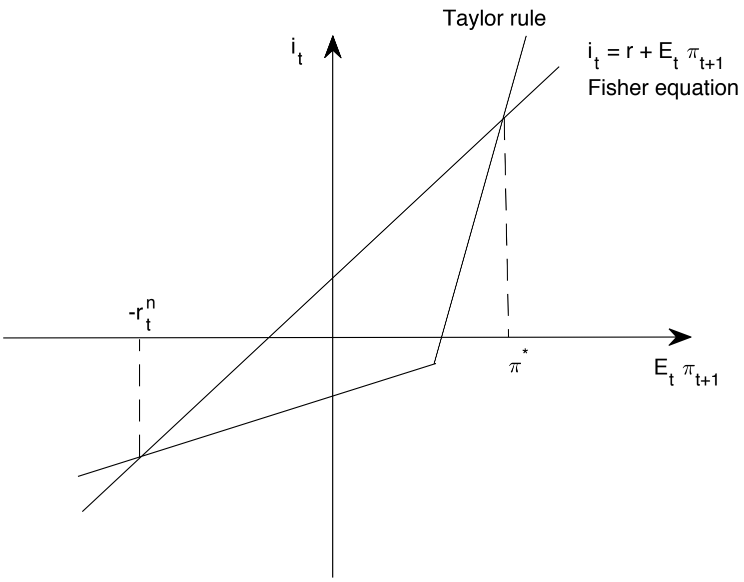

FIGURE 3.2: An active Taylor rule have two equlibria: a bad one $-r_t^n$ and a good one π^* which corresponds to the inflation target. However, the system can converge towards the bad equilibrium characterized by deflation and low interest rates $-r_t^n$ (Williamson et al., 2018).

The figure shows what is the inflation path which we have under an active monetary policy and the ZLB. In this scenario, there are two steady state equilibria. Therefore, as we have already said, is a good equilibrium in which central bank reaches inflation target and therefore $\pi_t = \pi^*$, and a bad equilibrium where economy reaches the Zero Lower bound and it is affected by a deflation spiral; in this scenario, as stated by Williamson et al. (2016), central bank tries to keep nominal interest rate near zero with the hope that inflation will raise but it will not. Moreover, many equilibria of the system converge to the ZLB steady state. On the one hand, for each $\pi_0 < \pi^*$ the system converges to the ZLB steady state equilibrium, on the other hand, if $\pi_0 > \pi^*$ inflation will raise with no bound. Thus, central bank, in order to determinate the system through an active monetary policy, will introduce instability. The behaviour that we have just introduced is a good explanation of what it is happening in the most of the Western countries and Japan. The idea is that, Fed, ECB, BoJ, Bank of England, Sveriges Riksbank and many other central banks which have been applying ZIRP for long period, are pushing the economy towards the bad equilibrium, characterized by almost zero interest rate and low inflation, rather than recovering the system.

4. Analysis and Estimation results

This chapter is devoted to the most empirical part of the research. Indeed, this section is divided into two different analysis. In the first part of the analysis, a baseline New Keynesian model is set and calibrated in order to check if inflation and nominal interest rate can move together after a monetary policy shock, showing up a Fisherian effect. Accordingly to the theory analyzed, I expect that the more persistent will be the monetary policy shock then the higher is the probability of a co-movement between the two variables. Therefore, an increase in the autoregressive coefficient of the monetary shock should support the New-Fisherian Hypothesis. If so, it assumes sense to estimate the persistence of the shock using real data. Therefore, in the second part of the analysis, real data regarding Swedish macro-variables will be fit in the model in order to estimate the autoregressive coefficient of a monetary policy shock and to check whether it is possible to have New-Fisherian evidences in the Scandinavian country.

4.1 Methodology

In the first part, a baseline New Keynesian model is set and calibrated following the literature. Then, in order to check when New the Keynesian models show New-Fisherian response, a monetary policy shock is simulated for two different values of the autoregressive coefficient of the Taylor shock. This part follows the research conducted by Garín et al. (2018) in which the authors find that the more persistent is the inflation target and the less the prices are sticky then the higher is the Fisherian effect in the New Keynesian model. The baseline New Keynesian which is employed is the same introduced by Galí (2015). The model is reported here for simplicity:

$$y_t = \mathbb{E}_t\{y_{t+1}\} - \frac{1}{\sigma}(i_t - \mathbb{E}_t\{\pi_{t+1}\})$$

$$\pi_t = \beta\mathbb{E}_t\{\pi_{t+1}\} + k\tilde{y}_t$$

$$i_t = \phi_\pi \pi_t + \phi_y \tilde{y} + \theta_{i,t}$$

this is the same model which in the first chapter has been derived and described. Although the most of the parameters inside the model will be calibrated following Galí (2015)[1], the persistence of the monetary policy shock will assume two different values in order to compare the results. The calibration of the model's structural parameters is reported in Table 4.1.

σ	Intertemporal elasticity of substitution	1
β	Discount factor	0.99
φ	Inverse of Frisch elasticity of labour supply	1
α	Labor elasticity in the production function	1/3
θ	Calvo parameter	2/3
ϵ	Elasticity of substitution between goods	6
ϕ_{pi}	Reaction coefficient on inflation	1.5
ϕ_y	Reaction coefficient on output	0.5/4
ρ_θ	Persistence of the monetary policy shock	0.5 and 0.9
ρ_a	Persistence of the TPF shock	0.9
σ_θ	Standard deviation of the monetary policy shock	0.25
σ_a	Standard deviation of the TPF shock	0.25

Table 4.1: Calibration of the model's structural parameters.

In order to solve the linear rational expectation model I employ the method proposed by Blanchard and Kahn (1980) and then extended by King and Watson (1998).

In the second part of this analysis, the Swedish data concerning inflation, GDP and nominal interest rate are fitted in the same model as before. The data serve the purpose to estimate the autoregressive coefficient of the monetary policy shock in Sweden. The estimation will be conducted using dataset containing information which goes from 1987-2017. The idea is to check whether the autoregressive coefficient in Sweden is high enough to justify a synchronization between inflation and nominal interest rate. Indeed, as shown in Figure 4.1, the time series of nominal interest rate and inflation seem to move cyclically rather than counter-cyclically.
Furthermore, in order to enrich the analysis, the dataset will be divided into two samples - pre- and post-crisis. Indeed, the idea is to investigate if the Great Recession caused a structural change in the perception of the persistence of the monetary policy shock. Moreover, since Sweden economy has been characterized by prolonged zero interest

[1]Galí (2015) calibrates the parameters of both the dynamic IS and the NKPC following Galı et al. (2001) who use aggregate data in order to estimate them. The values of the coefficient in the Taylor rule are chosen in accordance with Taylor (1999). This calibration is widely used by macroeconomists.

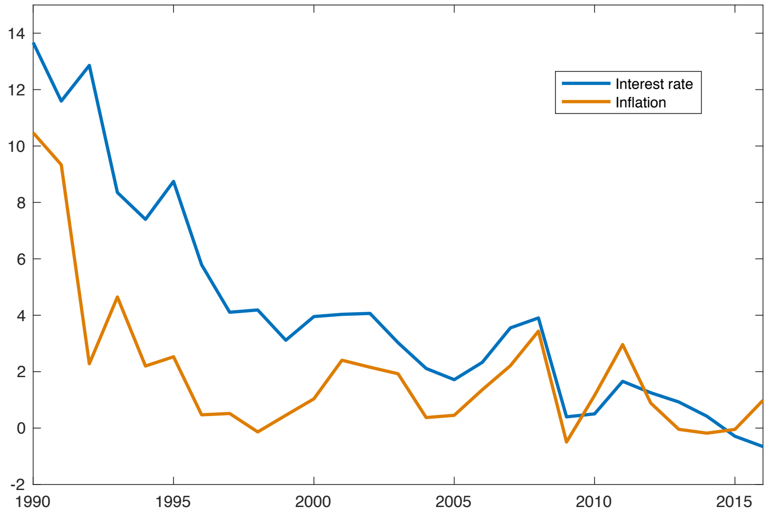

FIGURE 4.1: Inflation and short nominal interest rate in Sweden, 1995-2016

rate, and even negative in the very last period, it is possible to use the period after crisis as a proxy for zero interest rate state. For the purpose, will be used *Dynare* which is a software able to solve DSGE and Overlapping Generation model (OGM), and, through the Bayesian technique, to estimate the parameters in the model given a dataset (Adjemian et al., 2011).

4.2 Bayesian estimation

In this section is introduced the Bayesian approach. In the Bayesian estimation, the parameter is considered as a random variable; therefore, it is described by a probability distribution. Such distribution is first described by ($\pi(\theta)$), called *a priori*, that represents the beliefs about how the parameter is distributed before that data are observed. The distribution *a priori* can be retrieved from similarities with other independent observations, personal beliefs and/or the literature. Then, once the data are collected, through the Bayes's theorem, the data distribution ($f(\mathbf{y}|\theta)$) is used to evaluate the so called *posterior* distribution. Indeed, the Bayes' theorem allows to combine the information about the parameter obtained by the *a priori* and the data distribution in order to get the *posterior* distribution (Gelman et al., 2014). The *posterior* is obtained by:

$$\pi(\theta|\mathbf{y}) = \frac{f(\mathbf{y}|\theta)\pi(\theta)}{\int f(\mathbf{y}|\theta)\pi(\theta)d\theta} \tag{4.1}$$

or equivalently:

$$\pi(\theta|\mathbf{y}) \propto L(\theta;\mathbf{y})\pi(\theta) \tag{4.2}$$

where $L(\theta;\mathbf{y})$ is the likelihood function. The (4.2) is particularly useful for Maximum Likelihood estimation (MLE); indeed, it allows to not compute the integral in the denominator of the (4.1) and, therefore, to simply the final evaluation. One difference with respect to the frequentist approach is that, while the frequentist considers the unknown parameter as fixed and observable through many trials, the Bayesian approach, considers the unknown parameter as the same as a random variable. Therefore, since the Bayesian approach considers the unknown parameter as a random variable rather than an unknown number, it is possible to describe our knowledge about the parameter with the prior information. Sometimes, well defined such *a priori* distribution, this methodology could give more robust and reliable results (Cox et al., 1946).

4.3 Interest rate response with simulated data

In this section, I calibrate the model as Galí (2015) does and I check if interest rates and inflation move together. I report the Impulse response functions of nominal interest rate and inflation given a 1% Taylor shock. The results are reported in Figure 4.2

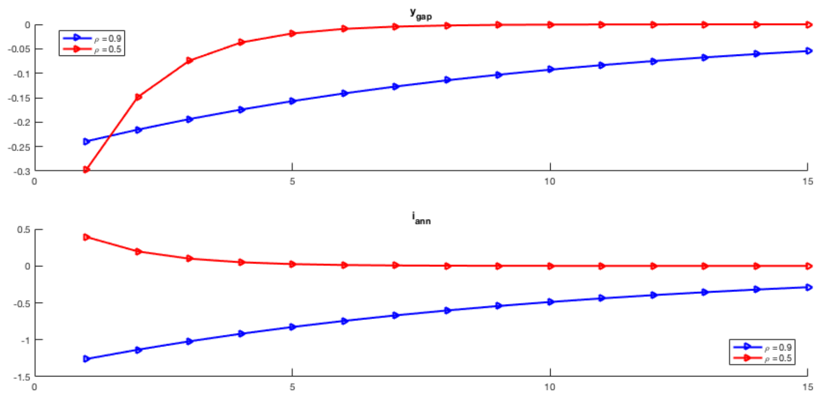

FIGURE 4.2: Monetary policy shock - IRF simulation

As we can notice from Figure 4.2 if $\rho = 0.5$, a monetary policy shock leads to expected results; indeed, given a positive shock of 1%, nominal interest rate raises and inflation decrease. On the other hand, if I increase the autoregressive coefficient $\rho = 0.9$ the results we get are New-Fisherian. Indeed, increasing the persistence of the shock would reduce both inflation and nominal interest rate. Therefore, these results suggest that nominal interest rate and inflation can move in the same direction. The co-movement between them is due to rational expectation of the agents. Indeed, since nominal interest rate depends also on inflation[2], if the shock on monetary policy is really persistent, agents perceive that such positive shock will result in lower output and inflation. Therefore, the reduction of expected inflation, through the NKPC, leads to less inflation today which will reduce also the nominal interest rate today. The process will be the following:

$$\theta_{t,i} \uparrow \rightarrow \ i_t \uparrow \rightarrow \ \mathbb{E}_t \pi_{t+1} \downarrow \rightarrow \ y_t \downarrow \rightarrow \ \pi_t \downarrow \rightarrow \ i_t \downarrow$$

Hence, we find the co-movement between inflation and nominal interest rate in the short-run. Thus, as stated by Cochrane (2017), the co-movement between the two variables is not present just in the long run but also in the short one. The expectations of the agent play a fundamental role; indeed, they are stronger than any frictions in the model and lead to Fisherian results. Therefore, New-Fishierities claim that an increase in the nominal interest rate can toss inflation rate rather than reducing it. In particular, they sustain that, at the ZLB, increasing nominal interest rate is needed in order to restore expectations regarding inflation and to boost the economy. The next step it will be to fit the real data in the model and to verify whether the Fisher effect will still be observable.

4.4 Swedish case

In this section, a Bayesian analysis is conducted in order to estimate the autoregressive coefficient of a monetary policy shock in Sweden. The data used are quarterly data[3] spanning the period 1987:Q1 to 2017:Q4. The dataset contains information regarding short nominal interest rate, GDP and Consumption price index. Moreover, in order to check whether the Great Recession caused a structural change in the perception of the monetary policy shock, the datset has been divide into two samples: (i) a period pre-crisis which goes from 1987:Q1 to 2007:Q4 and (ii) the years after the crisis from 2008:Q1 to 2017:Q4. Although the model employed is the baseline New Keynesian model, an inflation shock has been added to the model in order to avoid identification problem[4]. Therefore, following Ifrim (2014), a shock has been added to the Phillips curve which becomes $\pi_t = \beta \mathbb{E}_t\{\pi_{t+1}\} + k\tilde{y}_t + \nu_t$ where $\nu_t = \rho_\pi \nu_{t-1} + \epsilon_{\pi,t}$ is an AR(1). While the persistence of the interest shock is estimated, all the other parameters are calibrated following the literature (Table 4.1) and $\rho_\nu = 0.8$ and the standard deviation of the inflation shock $\sigma_\pi = 0.25$ (Ifrim, 2014). Conversely, regarding ρ_θ, the prior chosen

[2]Remember: $i_t = \phi_\pi \pi_t + \phi_y \tilde{y} + \theta_{i,t}$
[3]In Appendix D is how the data are constructed
[4]Otherwise the likelihood function is not well-defined.

is a Beta probability density distribution with mean 0.75 and standard deviation 0.1. The parameter is estimated with a Bayesian confidence interval of 90%.

4.4.1 Posterior distributions

In this section, the results are shown. The posterior distributions along with the prior distributions are reported in Appendix B. The posterior distributions of both the analysis - all the sample, before the crisis and after the crisis - are very close to their priors. However, the autoregressive coefficient is much higher after the crisis; indeed, if all the sample is considered then $\rho_\theta = 0.59$, the persistence of the shock after the Great Recession is about $\rho_\theta = 0.7$ while before the crisis is $\rho_\theta = 0.58$. Therefore, these results highlight a change in the persistence of the monetary policy shock after 2008.

4.4.2 Impulse Response functions

This division is devoted to the Impulse response functions. Here, the Impulse response functions, after a monetary policy shock, are reported with a Bayesian confidence interval of 90%. The effects of both the technology shock and the inflation shock are not shown since the research is devoted just to the transmission of a monetary policy shock to the economy.

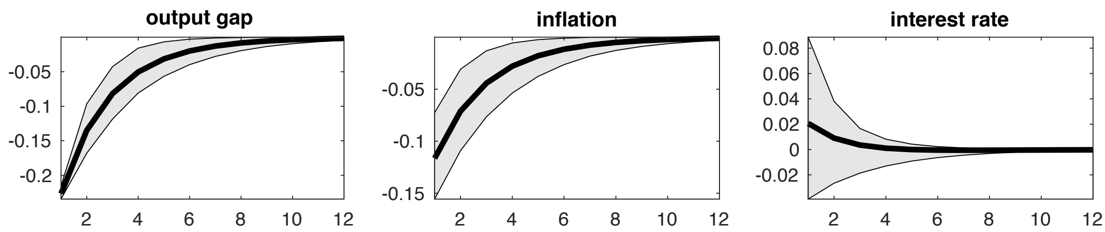

FIGURE 4.3: Monetary policy shock - IRF 1987-2017

In Figure 4.3 are reported the impulse response functions evaluated for all the sample (1987-2017)[5]. The persistence of the monetary policy shock is about $\rho_\theta = 0.59$. The results are the same expected by the mainstream literature; indeed, a monetary policy shock increases nominal interest rate and therefore, through the channel of the real rate, decreases both output gap and inflation. Therefore, all the macro variables respond accordingly to the orthodox theory. Conversely, if the Impulse response functions are evaluated using the estimated ρ_θ in the period after crisis, the results obtained are interesting and in accordance with the New-Fisherian view.

[5]The Impulse Response function for the period 1987-2007 are very similar to those in all the sample; therefore will not be reported here.

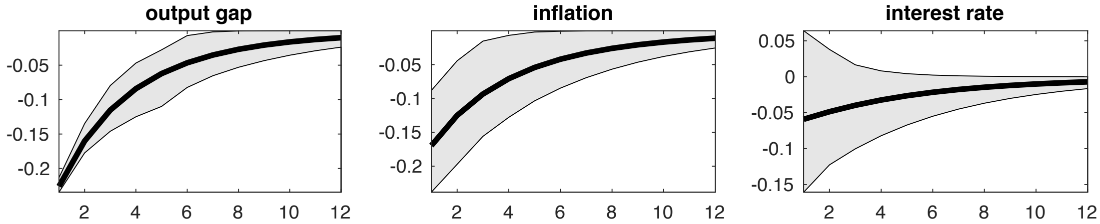

FIGURE 4.4: Monetary policy shock - IRF 2008-2017

As shown by Figure 4.4, a positive interest rate shock decreases both output gap, inflation and interest rate. This result confirms that it is possible to find evidences of New-Fisheriansm if the persistence of monetary shock is above 0.7;indeed, both inflation, output and nominal interest rate decrease. Therefore, in the aftermath of the Great Recession, inflation is much more linked to nominal interest rate. In this new landscape, New-Fisherities suggest that, in order to increase inflation, it is necessary to hike nominal interest rate; they state that, since the new positive relationship between nominal interest rate and expected inflation, a policy such as forward guidance could lead to unexpected results, this is due to the fact that prolonged almost zero nominal interest rate pin down inflation rather than increasing it.

5. Conclusion

In the aftermath of the Great Recession, in the most western countries, nominal interest rates have been low in order to recover the economy. Indeed, all the central banks - in accordance with the Taylor rule - have been keeping nominal interest rate very low, even negative, with the hope that inflation and output increased. However, such a policy did not bring the expected results and, therefore, central banks had to turn to unconventional monetary policies, i.e. Quantitative easing and Forward guidance. Although output showed up improvements, inflation seems to be very low and quite despite the prolonged ZIRP. Furthermore, in this new economics landscape, even if US did not reach the inflation target yet, Fed has been increasing nominal interest rate since early 2016; therefore, it opens the room for a new debate regarding the effect of increasing nominal interest rate when inflation is still below the target. This discussion is carried out by a new *school of thought* called New-Fisherianism and sustained by important economists such as Bullard, Williamson and Cochrane. In this work, I first introduced the baseline New Keynesian model and, then, I tried to present this new literature, highlighting when the New-Fisher effect can arise and where the mainstream New Keynesian models fail to produce precise results. I found that, when the persistence of the shock is high, then, nominal interest rate and inflation can move in the same direction also in the New Keynesian model; in agreement with New-Fisherities. Furthermore, since Sweden is one of the countries which has been suffering from stubborn low-inflation, I fit in the DSGE data regarding GDP, nominal interest rate and inflation in order to estimate the magnitude of the autoregressive coefficient of a monetary policy shock. The persistence of the shock, in Sweden, for the period which goes from 1987 to 2007, seems to be lower than the period after crisis; this highlights a structural change in the perception of the persistence of the monetary policy shock in 2008. Moreover, if I simulate the Impulse response functions, with a Bayesian 90% confidence interval, given the estimated parameters, the impulse response functions in the sub-sample 2008-2017 are New-Fisherian; indeed, both nominal interest rate and inflation decrease. Therefore, in the aftermath of the Great Recession inflation and nominal interest rate are more likely to follow the same path. New-Fisherities sustain that this is due to the fact that inflation is strongly linked to nominal interest rate, through expectations, and therefore, forward guidance, for instance, pin down prices rather than increasing them. Therefore, this new school of thought claims that, in order to increase inflation, it is necessary to hike nominal interest rate which will work as positive shock to expected inflation.

In a further perspective, it could be interesting to estimate all the parameters in the model and not just the persistence of the monetary policy shock. Moreover, a micro-data analysis in order to check what is the effect of increasing nominal interest rate on expectations regarding inflation could be an important way of approaching the subject in order to implement this recent literature.

A. Taylor Approximation

In order to turn the system of non-linear equations into a system of linear ones we can employ the methods based on the first order Taylor series approximation (Taylor, 1715). Such method is based on the following relation:

$$f(X_t) \approx f(X) + \frac{\delta f(X)}{\delta X}(X_t - X) \tag{A.1}$$

we can rewrite (A.1) as:

$$f(X_t) \approx f(X) + \frac{\delta f(X)}{\delta X} X \frac{(X_t - X)}{X} \tag{A.2}$$

where $\frac{(X_t - X)}{X} = \frac{X_t}{X} - 1 \approx ln\frac{X_t}{X} = ln(X_t) - ln(X) = (x_t - x)$ is the % of deviation from the steady state. Therefore, if $(x_t - x) = \widehat{x}_t$ we can rewrite (A.2) as:

$$f(X_t) \approx f(X) + \frac{\delta f(X)}{\delta X} X \widehat{x}_t \tag{A.3}$$

we can now rearrange (A.3), in order to get:

$$f(X_t) - f(X) \approx \frac{\delta f(X)}{\delta X} X \widehat{x}_t \tag{A.4}$$

and dividing both side by $f(X)$, we obtain:

$$\frac{f(X_t) - f(X)}{f(X)} \approx \frac{\frac{\delta f(X)}{\delta X}}{f(X)} X \widehat{x}_t \tag{A.5}$$

where $\frac{\frac{\delta f(X)}{\delta X}}{f(X)} X$ is the elasticity of $f(X_t)$ at the steady state.

B. Posterior distributions

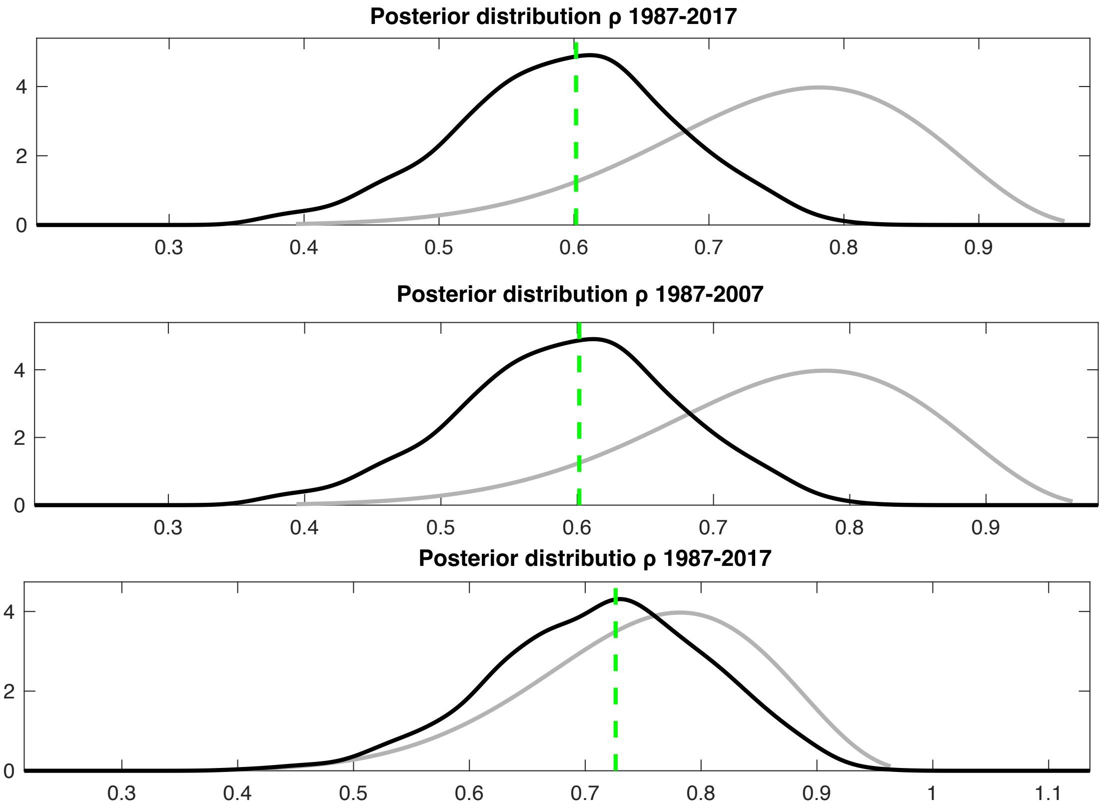

Figure B.1: Posterior Distributions

C. Solution through lag-operator of Inflation and interest rates paths

Consider the baseline New Keynesian model with a central bank mono-mandate[1]:

$$\tilde{y}_t = \mathbb{E}\{\tilde{y}_{t+1}\} - \frac{1}{\sigma}(i_t - \mathbb{E}\{\widehat{\pi}_{t+1}\} - r_t^n) \tag{C.1}$$

$$\widehat{\pi}_t = \beta\mathbb{E}\{\widehat{\pi}_{t+1}\} + k\tilde{y}_t \tag{C.2}$$

$$i_t = \phi_\pi \pi_t + \theta_{i,t} \tag{C.3}$$

$$\theta_t = \rho_i \theta_{i,t-1} + \eta_{i,t} \tag{C.4}$$

where for simplicity $r_t^n = 0$. We can substitute (C.4) (C.3) into (C.1), and express in lag operator notation:

$$\mathbb{E}_t(1 - L^{-1})(1 - \beta L^{-1})\pi_t = \frac{1}{\sigma}k\mathbb{E}_t(L^{-1} - \phi_\pi)\pi_t - \sigma k \theta_{i,t} \tag{C.5}$$

which is equal to:

$$\mathbb{E}_t \left(1 - \underbrace{\frac{1 + \beta + \sigma k}{1 + \sigma k \phi_\pi}}_{\lambda_1} L^{-1} \right) \left(1 - \underbrace{\frac{\beta}{1 + \sigma k \phi_\pi}}_{\lambda_2} L^{-1} \right) = -\frac{\sigma k}{1 + \sigma k \phi_\pi}\theta_{i,t} \tag{C.6}$$

where:

[1] It has just an inflation target.

$$\lambda = \frac{1 + \beta + \sigma k \pm \sqrt{(1 + \beta + k\sigma)^2 - 4\beta(1 + \phi_\pi \sigma k)}}{2(1 + \sigma k \phi_\pi)} \tag{C.7}$$

therefore, since $\phi_\pi > 1$ for the Taylor principle then $\lambda_{1,2} < 1$.

Thanks to the properties of the shock $\theta_{i,t}$ which is an AR(1), is possible to rewrite (C.6):

$$\pi_t = -\frac{\sigma k}{1 + \sigma k \phi_\pi} \left(\frac{1}{(1 - \lambda_1 \rho)(1 - \lambda_2 \rho)} \right) \theta_{i,t} \tag{C.8}$$

moreover, if we insert (C.8) into (C.4), we can find the nominal interest rate path which is:

$$i_t = \left[1 - \frac{\phi_\pi \sigma k}{1 + \sigma k \phi_\pi} \left(\frac{1}{(1 - \lambda_1 \rho)(1 - \lambda_2 \rho)} \right) \right] \theta_{i,t} \tag{C.9}$$

D. Data

The data used for the Bayesian estimation are quarterly data spanning the period 1987:Q1 to 2017:Q4. The dataset contains the following variables regarding Sweden:

- Real GDP (GDP)
- Consumer Price index (CPI) (Index 2010=100)
- Interbank Rates: 3-months (int)

Following Ifrim (2014) all the data have been transformed in order to fit in the model in this way:

- $\pi_t = log\left(\frac{CPI_t}{CPI_{t-1}}\right) - log\left(mean\left(\frac{CPI_t}{CPI_{t-1}}\right)\right)$
- $i_t = log\left(1 + \frac{int_t}{400}\right) - mean\left(log\left(1 + \frac{int_t}{400}\right)\right)$
- $\tilde{y}_t = log(GDP_t) - log(GDP_t^{trend})$

where, through the Hodrick-Prescott filter (see Hodrick and Prescott, 1997), the cyclical component and the trend component for GDP have been divided.

The data regarding GDP are contained in the Eurostat database, while both Interest rate and Consumer Price index are stored in the OECD database. However, all the variables have been retrieved from FRED, Federal Reserve Bank of St. Louis[1]

[1] https://fred.stlouisfed.org

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