Department of Economics

Athens University of Economics and Business

WORKING PAPER no. 13-2023

A DSGE Model for the European Unemployment Persistence

Konstantinos Giakas

August 2023

Πατησίων 76, 104 34 Αθήνα. Τηλ.: 210 8203303-5. E-mail: econ@aueb.gr / www.aueb.gr
76, Patission Street, Athens 104 34 Greece. Tel.: (+30) 210 8203303-5

A DSGE Model for the European Unemployment Persistence

Konstantinos Giakas*

August 2023

Abstract

Standard unit root tests show that European unemployment is characterized by a high degree of persistence. Motivated by this finding, we develop a monetary DSGE model of unemployment which highlights financial frictions along with employment hysteresis. The model is calibrated for the Eurozone. Impulse response analysis indicates that the model can generate very persistent business cycle fluctuations after an aggregate shock. Moreover, after a negative capital quality shock, which we use to simulate a financial crisis, welfare analysis indicates that wage inflation stabilization implies less losses relative to price inflation stabilization. It is shown that these benefits increase with the degree of hysteresis. Since 2014 the ECB has implemented various large-scale asset purchase programmes, commonly known as QE. We use the developed model to examine the macroeconomic effects of such unconventional monetary policies. We show that, after a strong financial shock, an unconventional monetary policy modeled as a government intervention in credit, can lead to significant welfare benefits, which tend to increase with the magnitude of the recession.

Keywords: employment hysteresis, financial frictions, monetary policy, quantitative easing, unemployment fluctuations.

JEL classification numbers: E24, E32, E52.

This research did not receive any specific grand from funding agencies in the public, commercial, or non-for-profit sectors.

Declarations of interest: none.

*Athens University of Economics and Business, Department of Economics, 76 Patission Street, GR 10434, Athens, Greece, email: giakask@aueb.gr

1 Introduction

The empirical macro literature has produced a strong set of empirical results that emphasize the persistent nature of European unemployment fluctuations. Indeed, Blanchard & Summers (1986) were the first to introduce the term "hysteresis" to describe the significant persistence of the European unemployment rates after the economic crises of the 1970s and 1980s. This substantial persistence of the European unemployment, although it appears to gradually deescalate, still remains very high even during the more recent European Monetary Union period[1]. Standard medium-scale DSGE models cannot explain this persistence, without resorting to unrealistically strong exogenous shocks.

Since 1999, the European Central Bank (ECB) has been responsible for conducting monetary policy in the countries that have adopted the euro as their currency. During "normal times" the ECB's primary objective is to maintain price stability within the euro area, aiming for an inflation rate of close to but below 2% over the medium-run. Empirical evidence shows that financial crises, like the one of 2008, tend to generate very persistent business cycle fluctuations. In response to this global financial crisis of 2008 and the subsequent European sovereign debt crisis, the ECB, like many other central banks, implemented unconventional monetary policy measures to accommodate economic recovery and stabilize financial markets[2]. These unconventional monetary policy measures were taken as more traditional tools of interest rate adjustments had (to some extent) lost their potency. Thus, central banks had to resort to large-scale asset purchases, also referred as quantitative easing (QE)[3].

In 2014 after a severe drop in inflation rates and medium-term inflation expectations, the ECB introduced its first Asset Purchase Programme (APP)[4] with a total monthly purchase volume of between 60 and 80 billion euros[5]. The ECB's APP was intended to complement standard interest rate decisions, rather than substituting them. Its application has been instrumental in supporting the Eurozone economy as a whole, aiding financial stability, and countering deflationary pressures [6].

The scope of this paper is twofold. Firstly, we develop a DSGE model that generates strong endogenous persistence for European unemployment as the one observed after severe economic contractions. In this context, emphasis is given on the role of employment hysteresis and how this amplifies the effects of temporary aggregate shocks. Secondly, to investigate the implications of hysteresis in the propagation of monetary policy either during "normal times" or during financial crises.

The core of the developed model is based on the typical medium-scale New Keynesian model of Smets & Wouters (2007) and Christiano et al. (2005), which is extended towards two main directions. Firstly, to incorporate employment hysteresis as in Galí (2022). Secondly, to introduce financial intermediaries that face endogenously determined balance sheet constraints as in Gertler & Kiyotaki (2010) or Gertler & Karadi (2011).

Overall, the model economy consists of households, financial intermediaries, intermediate and retail good producing firms, capital good producers, a government, and a monetary authority. A household member is either a

[1] As we show in section 2.

[2] Since 2008 such measures have been conducted by, among others, the Federal Reserve (Fed), the ECB, the Bank of England, and the Bank of Japan.

[3] QE programmes are one of a variety of unconventional monetary policy tools, collectively labeled "enhanced credit support", available to a central bank. In the context of the euro area, other unconventional monetary policies employed by ECB included: Long-Term Refinancing Operations (LTROs), Targeted Longer-Term Refinancing Operations (TLTROs), negative deposit facility rates and the use of forward guidance. The whole spectrum of non-standard policy measures adopted by the ECB during the Great Recession is discussed in detail by Micossi (2015).

[4] The APP is actually a more general term for four different purchase programmes: the Third Covered Bond Purchase Programme (CBPP3), the Asset Backed Securities Purchase Programme (ABSPP), the Public Sector Purchase Programme (PSPP), and the Corporate Sector Purchase Programme (CSPP).

[5] The initial size of 60 billion euros per month was increased to 80 billion euros in March 2016 and lowered again to 60 billion euros in December 2016.

[6] In March 2020, the ECB responded to the onset of the Covid-19 pandemic by launching a new 1,350 billion euros Pandemic Emergency Purchase Programme (PEPP) aimed to lower borrowing costs and increase lending in the euro area. The PEPP was extended to cover an additional 500 billion euros in December 2020. As of 2021, the size of the ECB's QE programme had reached 2,947 billion euros.

worker or a banker. Financial intermediaries (banks) borrow funds from households and then lend these funds to intermediate good producers. The financial intermediary gains from expanding her assets indefinitely, and she does so by borrowing additional funds from households. A limit is imposed on this ability by introducing a moral hazard problem[7].

The labor force is divided into two segments with opposing interests: the employed, referred to as insiders, and the unemployed, called outsiders. Then employment hysteresis is introduced by assuming that monopoly labor unions that represent insiders, unilaterally set the nominal wages to ensure employment for their members according to a hysteresis equation. Unemployment is modeled in the extensive margin as in Galí (2011b) and Galí (2022).

The model is calibrated using standard euro area parameter values and then we examine the propagation of two aggregate shocks, a monetary policy shock and a capital quality shock. Both shocks are considered relevant to the onset of financial crises. Quantitative results indicate that employment hysteresis amplifies their impact on the economy. In addition, welfare analysis reveals that a monetary policy rule that stabilizes wage inflation rather than price inflation leads to lower welfare losses. As we show, the relative gains from such policy appear to increase with the degree of hysteresis.

Finally, we allow for unconventional policy through government interventions in credit. We show that after a negative capital shock, the use of government credit stabilizes the model economy more effectively relative to standard conventional monetary policy. In addition, more effective stabilization implies significantly higher welfare. We show that these welfare gains increase with the shock's magnitude.

The rest of this paper is organized as follows. In subsection 1.1 we present a brief review of the relevant literature. Section 2 presents empirical evidence that highlights the high persistent nature of the European unemployment rate. Section 3 describes the theoretical model. Section 4 presents the model's calibration and the quantitative results. Finally, section 5 summarizes some conclusions.

1.1 Related Literature

Both older and more recent empirical studies strongly support that the European unemployment is characterized by a high degree of persistence, for instance Clark & Summers (1982), Ellwood (1982), Blanchard & Summers (1986), Cerra & Saxena (2000), Bluedorn & Leigh (2018), Bluedorn & Leigh (2019) and Galí (2022). An up-to-date survey on hysteresis can be found in Cerra et al. (2020).

Moreover, empirical evidence shows that financial crises tend to generate very persistent business cycle fluctuations. More specifically, Claessens et al. (2012) using data from 44 OECD and 23 emerging market countries, finds that recessions associated with financial crises are longer and deeper relative to other recessions. Jordá et al. (2011) focuses on data from 14 advanced countries and shows that financial crises are costlier, tend to be followed by deeper recessions and slower recoveries relative to typical recessions. Reinhart & Rogoff (2014) studies the evolution of real output after 100 systemic banking crises and finds that a large portion of the costs of these events lie in the prolonged and halted nature of the recovery. Ball (2014) uses data from 23 countries and finds that most of these countries have experienced strong hysteresis effects on their real output, after the 2008 global financial recession.

Macroeconomic modeling was also affected by the Great Recession of 2008 and its aftermath. Macro-economists became more focused on financial frictions to provide a plausible explanation for the origins and the evolution of the crisis. It is indicative that, as the financial crisis unraveled, a plethora of models which introduced financial frictions into DSGE models emerged[8], Mendoza (2010), Meh & Moran (2010), Gertler & Kiyotaki (2010), Gertler

[7] Within this framework, financial frictions arise in the supply of credit. Essentially, frictions in the supply of credit assume that the banking sector is problematic.

[8] Efforts to incorporate financial frictions into dynamic macroeconomic models had already started since the late 1980s with Bernanke & Gertler (1989), Bernanke & Gertler (1990), Holmstrom & Tirole (1997), Iacoviello (2005) and the seminal papers of Kiyotaki & Moore (1997) and Bernanke et al. (1999).

& Karadi (2011), Cúrdia & Woodford (2010), Cúrdia & Woodford (2011), Jermann & Quadrini (2012), Kiyotaki & Moore (2012) and Iacoviello (2015) among many others[9]. These models highlighted elaborate mechanisms that endogenously incorporated frictions either in the demand or in the supply for credit. These mechanisms, in some cases, generated more endogenous persistence relative to a financially frictionless version of the model. This characteristic became known as the "financial accelerator" effect.

Furthermore, since the start of the first QE programme by the Bank of Japan in 2001, a continuously growing literature on the effects of QE programmes has also emerged. As pointed out by Borio & Zabai (2018), the distinguishing feature of these programmes is that the central bank uses the quantity of assets on its balance sheet to affect market prices and conditions beyond a short-term interest rate. Therefore, central bank balance sheets have expanded substantially. In advanced economies, central bank assets now exceed 20% of GDP. Moreover, unconventional monetary policies have led to significant changes in terms of balance sheet composition as is shown in Borio & Zabai (2018) and Lenza et al. (2010).

A stream of this literature considers how large asset purchasing programmes can be built into standard New Keynesian models. As shown in Cúrdia & Woodford (2011), targeted asset purchases can be effective if financial markets are sufficiently disrupted, i.e., if private-sector financial intermediation is inefficient. Other examples are Sims & Wu (2020) and Sims & Wu (2021) who study the implications of different unconventional policies in the context of a DSGE model that highlights Gertler & Karadi (2011) financial frictions. A second approach is based on the limitation of arbitrage, which is modeled by assuming segmented asset markets, e.g., due to preferred-habitat motives as in Vayanos & Vila (2021). Similarly, Chen et al. (2012) aim to simulate the second large-scale APP by the Fed, by augmenting a standard DSGE model with segmented bond markets.

Nevertheless, the theoretical literature that concentrates in the euro area is not extensive. Instead, it is mostly empirical. Authors such as Mouabbi & Sahuc (2019) and Giannone et al. (2011) support the idea that without unconventional measures the euro area would have suffered a substantial loss of output since the Great Recession. Both studies conclude that ECB's non-standard monetary policy measures have supported monetary policy transmission and helped to avoid the calamity of the 1930s Great Depression. Similarly, Gambacorta et al. (2014) and Boeckx et al. (2017), show that unconventional monetary policy measures had positive and significant effects on the output of the Eurozone.

Studies such as Ferdinandusse et al. (2020), concentrate on the effects of ECB's APP on yields and liquidity. Urbschat & Watzka (2020) applies an event study approach to analyze the effects of ECB's QE announcements on financial markets, including bond yields, exchange rates, and equity prices. Jensen et al. (2017) investigate the transmission of the ECB's unconventional monetary policy measures, including the impact on exchange rates. Haitsma et al. (2016) analyze the impact of the ECB's conventional and unconventional monetary policy measures on stock market returns and volatility in the euro area. Pattipeilohy et al. (2013) examine the effectiveness of the ECB's unconventional monetary policy measures, including QE and LTROs, by assessing the impact of these measures on financial markets, inflation expectations, and bank lending. Gambacorta et al. (2014) analyze the effectiveness of unconventional monetary policy, including forward guidance and large-scale asset purchases, in mitigating the effects of the zero lower bound on interest rates across a sample of euro area countries. Pattipeilohy et al. (2013) suggest that while the ECB's balance sheet has increased dramatically during the crisis, the non-standard monetary policy measures had only a moderate impact on the composition of the ECB's balance sheet compared to other central banks such as the Fed and the Bank of England.

Other studies concentrate on the asymmetries in the transmission of ECB's monetary policy. For example, Burriel & Galesi (2018) show that euro area countries with more fragile banking systems benefit the least from unconventional monetary policy measures in terms of output gains. Jensen et al. (2017) study the impact of the ECB's large-scale QE programme on selected euro area and neighboring countries. Similarly, Elbourne et al. (2018)

[9] Analytical surveys of this literature can be found in Brunnermeier et al. (2012), Christiano et al. (2018) and Gertler & Gilchrist (2018).

investigate the effects of unconventional monetary policy in the individual countries of the euro area and in the Eurozone as a whole. The authors find weak evidence that expansionary unconventional monetary policy shocks increase output growth, but the effects on inflation at the aggregate euro area level are economically insignificant. Summing up, many authors, using different empirical methods, appear to find a positive impact of a QE policy on the economy, at least in the short-run. This is especially the case in times of financial crisis and general uncertainty. As we show later, our DSGE model captures this positive impact.
Our work is also related to Giakas (2023) who develops a calibrated DSGE model for the USA with Bernanke et al. (1999) type of financial frictions and examines the effects of alternative conventional monetary policy rules under different labor market structures. However, our model differentiates since; firstly, is calibrated for the Eurozone and secondly, the Gertler & Karadi (2011) type of financial frictions we adopt, allows us to examine the effects of ECB's QE.

2 Empirical Evidence

Figure 1 displays the unemployment rate for the Eurozone over the period 1970Q1 - 2022Q4, together with recession periods [10] depicted as shaded areas.

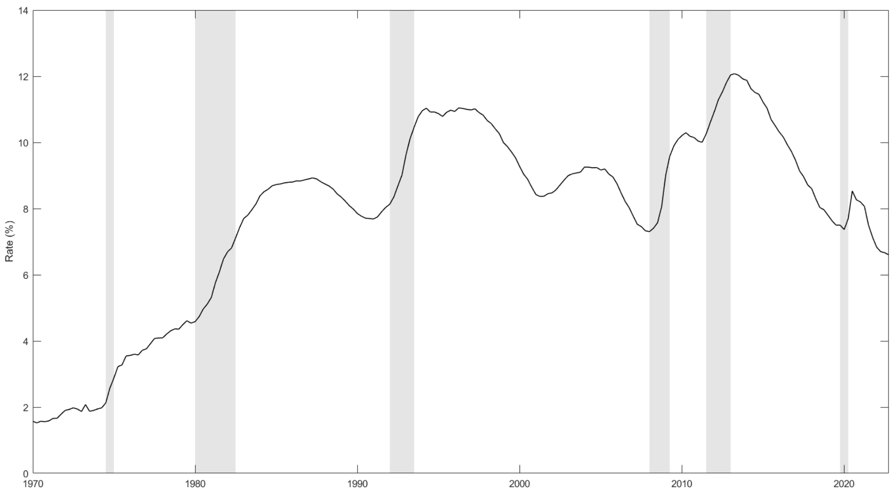


Figure 1: The European Unemployment Rate

The high persistence of the European unemployment rate can be seen by simply observing Figure 1[11]. In fact, we can notice that the European unemployment rate does not seem to fluctuate around a constant mean. On the contrary, each recession episode seems to pull the unemployment rate towards a new higher mean, around which it appears to stabilize. Then the unemployment rate either declines as the economy recovers or increases further if

[10] According to the CEPR-EABCN Euro Area Business Cycle Dating Committee, from 1970 until today, there are six Eurozone recession episodes:

- 1974Q3 - 1975Q1 : Due to the 1973 oil crisis, the first worldwide oil crisis, in which prices increased 400%.
- 1980Q1 - 1982Q3 : Due to the 1979 oil crisis, the second worldwide oil crisis, in which prices increased 100%.
- 1992Q1 - 1993Q3 : Due to the 1990 oil price shock (the "mini oil-shock"), in which prices increased for nine months.
- 2008Q1 - 2009Q2 : Due to the Great Recession that started in 2007 and lasted several years.
- 2011Q3 - 2013Q1 : Due to the European debt crisis that took place in the European Union from 2009 until the mid to late 2010s.
- 2019Q4 - 2020Q2 : Due to the COVID-19 pandemic that started in December 2019.

[11] Data were drawn from ECB's The Area Wide Model (AWM) & ECB's Statistical Data Warehouse.

a new recession hits (as in 1980 or 2008). While this tendency appears to have slightly deescalate during the more recent European Monetary Union period, fluctuations in the unemployment rate remain highly persistent until the end of the sample.

We test the previous observation by applying standard unit root tests to the euro area unemployment rate series. As reported in the Table 1, neither the Augmented Dickey-Fuller (ADF) nor the Phillips-Perron (PP) tests reject the null of hypotheses of unit root in the unemployment rate at any of the conventional levels of statistical significance (1%, 5% or 10%) for the full sample period. Similar results are obtained when we start the sample period in 1999Q1. The evidence makes it clear that the unemployment rate in the Eurozone displays very high persistence, even during the more recent single currency period.

	Unemployment Rate					
	1970Q1-2022Q4			1999Q1-2022Q4		
	Constant	Constant & Trend	Neither Constant nor Trend	Constant	Constant & Trend	Neither Constant nor Trend
ADF	-2.3514(1) (0.1570)	-1.3763(1) (0.8652)	-0.1479(1) (0.6316)	-1.6271(1) (0.4649)	-1.6680(1) (0.7579)	-0.8453(1) (0.3472)
PP	-2.1922(9) (0.2098)	-0.9299(9) (0.9496)	-0.0340(10) (0.6704)	-1.1785(6) (0.6812)	-1.2111(6) (0.9023)	-0.9800(6) (0.2908)

The first value on the first line is the t-statistic for the corresponding ADF or PP unit root test, the value in parentheses is the number of lags that were used for the test. The value in parentheses on the second line is the McKinnon (1996) one-sided p-value for the test.

Table 1: ADF and PP unit root tests results for the Unemployment Rate series

	1970Q1-2022Q4			1999Q1-2022Q4		
Level of Statistical Significance	Constant	Constant & Trend	Neither Constant nor Trend	Constant	Constant & Trend	Neither Constant nor Trend
1%	-3.4615	-4.0024	-2.5760	-3.4999	-4.0565	-2.5893
5%	-2.8751	-3.4314	-1.9423	-2.8919	-3.4573	-1.9442
10%	-2.5741	-3.1393	-1.6157	-2.5830	-3.1546	-1.6145

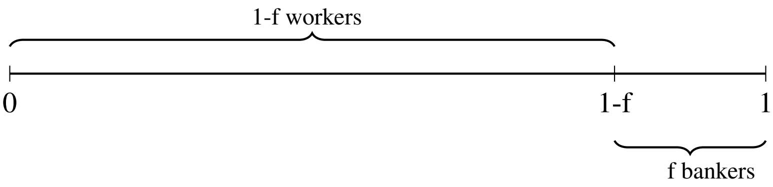
Table 2: Critical values for ADF and PP unit root tests

Standard medium-scale DSGE models cannot generate time series that are so persistent unless they resort to unrealistically strong exogenous shocks. As a matter of fact, during the past fifteen years DSGE models have been criticized for their dependence on strong exogenous shocks to generate time series of comparable persistence as in the “actual” macroeconomic data, see Chari & Kehoe & McGrattan (2009), Galí (2018) and Alogoskoufis (2019). As we will show later the developed model, that incorporates both employment hysteresis and financial frictions, has the potential to generate highly persistent business cycle fluctuations even after relatively weak exogenous shocks.

3 The Model

3.1 Labor Side

The economy is populated by many identical households of unitary measure. Household members are divided between workers and bankers. More specifically, a fraction 1-f of household members are workers, and a fraction f is bankers. Workers supply differentiated labor to intermediate good producers and return their wages to the household. Bankers on the other do not work but each one of them manages a financial intermediary and transfers dividend to the household. Within each household there is full consumption insurance.



Workers within each household are indexed by a pair (j,s) $\in [0, 1-f] \times [0, 1]$; where j $\in [0, 1-f]$ represents the type of labor service that a given worker is specialized in; and s $\in [0, 1]$ determines the disutility from work and is given by $\psi^n s^{\phi_n}$ if the worker is working and zero otherwise, ϕ_n denotes the elasticity with which workers of labor type j of the household enter or leave employment in response to aggregate shocks and ψ^n is a parameter that determines the disutility from work which is assumed to be constant among labor types.
Bankers within each household are represented by j $\in (1-f, 1]$. Furthermore, there is an iid probability $(1-\theta)$ that a banker does not survive to the next period[12]. When a banker exits the economy, she transfers all her remaining net worth to her household and then she becomes a worker. In addition, each period a number $(1-\theta)\,f$ of workers in each household randomly become bankers[13].
The representative household maximizes a dynamic utility function that is separable in consumption c_t, employment $n_{j,t}$ and per household government spending $\bar{g}$; and is given by the integral of its members' utilities.

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{(c_t - b^c c_{t-1})^{1-\sigma}}{1-\sigma} - \psi^n \int_0^{1-f} \int_0^{n_{j,t}} s^{\phi_n} ds dj + \psi^g \frac{\bar{g}^{1-\nu}}{1-\nu} \right) \tag{1}$$

where ψ^g, σ, ν are preference parameters, b^c is a measure of internal habit formation, β denotes the rate of time preference and $\int_0^{n_{j,t}} s^{\phi_n} ds = \frac{n_{j,t}^{1+\phi_n}}{1+\phi_n}$. The household maximizes its utility subject to a real period budget constraint of the form,

$$c_t + b_t \leq \int_0^{1-f} w_{j,t} n_{j,t} dj + r_t b_{t-1} + \Pi_t^r - \tau_t^l \tag{2}$$

where $r_t = \frac{1+i_{t-1}}{\pi_t}$ is the non-contingent real gross return received by the household at period t; $\pi_t = \frac{P_t}{P_{t-1}}$ denotes the quarterly gross inflation rate; b_{t-1} is the end-of-period real stock of short-term debt the household acquires[14], which pay off in period t the nominal interest rate known in period t-1, $1 + i_{t-1}$; $w_{j,t}$ is the real wage for labor of type j; Π_t^r denotes total real profits in the economy and τ_t^l are real lump-sum taxes/transfers paid by/to the household to/by the government. The intermediate firm optimally decides how much labor of each type j to employ by solving a cost minimization problem while taking wages as given. This gives the following sequence of labor demand equations,

$$n_{j,t} = \frac{1}{1-f} \left(\frac{W_{j,t}}{W_t} \right)^{-\epsilon_w} n_t^d \tag{3}$$

$\forall$ j $\in [0, 1-f]$, where n_t^d denotes the representative intermediate firm's aggregate demand for labor and $\epsilon_w \in$ (1, +∞) indicates the elasticity of substitution among labor types. The aggregate nominal wage index W_t is defined as

[12] In this case, the average survival time of a banker is $\frac{1}{1-\theta}$.

[13] Keeping, by this way, the total number of bankers in the economy constant.

[14] Either deposits to private banks or the sum of deposits to private banks and one period government bonds when government credit policy is applied.

$$W_t^{1-\epsilon_w} = \frac{1}{1-f}\int_0^{1-f} W_{j,t}^{1-\epsilon_w} dj \tag{4}$$

The sequences of constraints (2) and (3) are supplemented with a transversality condition on borrowing,

$$\lim_{k\to\infty} E_t \left\{\beta^k \frac{\lambda_{t+k}}{\lambda_t} b_{t+k}\right\} = 0 \tag{5}$$

where $\beta^k \frac{\lambda_{t+k}}{\lambda_t}$ is the real stochastic discount factor and λ_{t+k} is the period t+k Lagrange multiplier from the household's problem. At the optimum, the budget constraint (2) must hold with equality for every period t.

3.1.1 Calvo Wage Setting

Nominal frictions in the labor market are introduced by assuming that nominal wages are sticky in a Calvo (1983) setup. More specifically, $1-\theta_w$ is the probability of a labor type j to be able to reset wages next period and thus, θ_w^k is the probability of a newly set wage at time t, to still be in place at time t+k, $\forall$ k = 0,1,2,... If wages cannot be re-optimized, they are automatically updated according to the following indexation rule $W_{j,t+k|t} = W_{j,t}\left(\bar{\pi}^{\widetilde{\chi}k}\right)^{1-\widetilde{\mu}}\left(\pi^{\widetilde{\chi}}_{t-k,t+k-1}\right)^{\widetilde{\mu}}$ where $W_{j,t+k|t}$ denotes the wage set at period t+k by labor type j who last re-optimized its wage at period t, $\widetilde{\chi} \in [0,1]$ allows for any degree of nominal wage indexation, $\widetilde{\mu} \in [0,1]$ allows for any degree of combination of the two types of indexation; to steady state inflation $\bar{\pi}$ and to past inflation rates. $\widetilde{W}_{j,t}$ is defined as the optimal nominal wage set every period t. When re-optimizing their wage in period t, workers specialized in each occupation j choose a nominal wage $\widetilde{W}_{j,t}$ in order to maximize household utility given by eq. (1), subject to the budget constraint, eq. (2), the demand for labor in the specific market, given by eq. (3) and the probability of not being able to re-optimize in future periods. Solving the maximization problem gives the optimal nominal wage equation,

$$\widetilde{W}_t^{\epsilon_w\phi_n+1} = \frac{\epsilon_w}{\epsilon_w-1}\frac{1}{(1-f)^{\phi_n}}\frac{E_t\sum_{k=0}^{\infty}\beta^k\theta_w^k\psi^n\left[\frac{\left(\bar{\pi}^{\widetilde{\chi}k}\right)^{1-\widetilde{\mu}}\left(\pi^{\widetilde{\chi}}_{t-k,t+k-1}\right)^{\widetilde{\mu}}}{W_{t+k}}\right]^{-\epsilon_w(1+\phi_n)}\left(n^d_{t+k}\right)^{1+\phi_n}}{E_t\sum_{k=0}^{\infty}\beta^k\theta_w^k\lambda^n_{t+k}\left[\frac{\left(\bar{\pi}^{\widetilde{\chi}k}\right)^{1-\widetilde{\mu}}\left(\pi^{\widetilde{\chi}}_{t-k,t+k-1}\right)^{\widetilde{\mu}}}{W_{t+k}}\right]^{1-\epsilon_w}W_{t+k}n^d_{t+k}} \tag{6}$$

where $\widetilde{W}_t$ denotes the optimal nominal wage for labor type j which has no j index since all updating workers update to the same nominal wage.

3.1.2 Insiders-Outsiders Wage Setting

In this section, the labor sector of the model is modified to allow for the optimal wage to be determined in an insiders-outsiders context. We follow Galí (2022)[15], who builds upon the framework of Blanchard & Summers (1986), and assume that workers are segmented between those employed, called insiders, and those unemployed, called outsiders. The former possess a dominant role in wage determination. An employment target for each period $n^*_{j,t}$, which denotes the number of insiders in the model, is considered. The measure of insiders, or the employment target, in any given labor type j evolves over time according to the following hysteresis equation,

$$n^*_{j,t} = n^{\gamma}_{j,t-1}\left(\bar{n}^*\right)^{1-\gamma} \tag{7}$$

where parameter $\gamma \in$ [0,1] determines the extent to which changes in employment affect the economy's state, by

[15] Alogoskoufis (2018) presents an alternative way of modeling an insiders-outsiders labor sector, which is based on one period nominal wage contracts. The advantage of Galí's framework is that it can be introduced along with the Calvo (1983) assumption.

changing the portion of insiders. Moreover, $\bar{n}^*$ is the union's long-run target for employment, which is assumed to be common across labor types. According to eq. (7) when γ = 1, full hysteresis is assumed. Then employment, the unemployment rate and the rest of the model's variables are characterized by unit root behavior. Temporary shocks have permanent effects on these variables. On the contrary, when γ = 0, no hysteresis is assumed. In this case even after a strong temporary shock (with persistence close to unity), employment relatively quickly reverts to its steady state value.

The steady state level of employment is exogenously determined through the union's long-run employment target, i.e., $n = \bar{n}^*$. The intermediate firm optimally decides how much labor of each type to employ by solving a cost minimization problem while taking wages as given. Thus, aggregate demand for labor of type j and the aggregate nominal wage index are still given by equations (3) and (4), respectively. Each union is assumed to represent a specific labor type j. The union that is able to adjust its wage at period t+k, is sufficiently strong to unilaterally set the wage, $\widetilde{W}_{j,t}$, so as to make expected employment equal to its employment target, determined by eq. (7). The dynamic objective function of the j union is one where it attempts to maximize the intertemporal wage of insiders of type j it represents, subject to their employment being maintained. The discount factor is given by the product of the rate of time preference times the Calvo probability of a union not being able to adjust the wage of labor type j it represents,

$$\min_{\{n_{j,t}\}} \frac{1}{2} \sum_{k=0}^{\infty} (\beta\theta_w)^k \left(E_t \left\{n_{j,t+k|t}\right\} - n^*_{j,t}\right)^2$$

where $n_{j,t+k|t}$ is the t+k period demand for labor of type j whose wage has been optimized for last time in period t, $\forall$ k = 0,1,2... As in the standard Calvo wage setting, wages that are not optimally chosen in a specific period are adjusted to steady state and/or to past inflation according to the indexation rule $W_{j,t+k|t} = \widetilde{W}_{j,t} \left(\bar{\pi}^{\widetilde{\chi}k}\right)^{1-\widetilde{\mu}} \left(\pi^{\widetilde{\chi}}_{t-k,t+k-1}\right)^{\widetilde{\mu}}$. Assuming that all unions that can optimally choose their wage choose the same optimal nominal wage $\widetilde{W}_{j,t} \equiv \widetilde{W}_t$ $\forall$ j,t; the first order condition can be written as

$$\widetilde{w}_t^{\epsilon_w} = \frac{1-\beta\theta_w}{1-f} \sum_{k=0}^{\infty} (\beta\theta_w)^k E_t \left\{ w^{\epsilon_w}_{t+k} \left[\left(\bar{\pi}^{\widetilde{\chi}k}\right)^{1-\widetilde{\mu}} \left(\pi^{\widetilde{\chi}}_{t-k,t+k-1}\right)^{\widetilde{\mu}} \right]^{-\epsilon_w} \pi^{\epsilon_w}_{t,t+k} n^d_{t+k} \right\} n^{-\gamma}_{j,t-1} \left(\bar{n}^*\right)^{\gamma-1} \tag{8}$$

Eq. (8) is the optimal wage setting equation under the insiders-outsiders wage setting.

3.2 Financial Sector

3.2.1 Financial Intermediaries

The modeling of the financial sector follows Gertler & Karadi (2011). Financial intermediaries are assumed to borrow funds from households and then lend these funds to intermediate good producers. Apart from financial intermediation, their role also includes maturity transformation. More specifically, financial intermediary j $\in$ (1-f,1] holds long term assets and funds these assets with her own net worth $N_{j,t}$ and with short-term liabilities $b_{j,t}$, if her net worth is not enough. Her balance sheet in real terms is described by

$$q_t S_{j,t} = N_{j,t} + b_{j,t} \tag{9}$$

where $S_{j,t}$ denotes the quantity of financial claims on intermediate good producers that the banker j holds; and q_t denotes the relative price of each claim[16]. Households deposit funds to the financial intermediary j at time t; then they receive the non-contingent real gross return r_{t+1} at period t + 1. At the same time, financial intermediary's assets earn the stochastic return r^k_{t+1}. Both r^k_{t+1} and r_{t+1} are endogenously determined and the difference between

[16]As in Gertler & Karadi (2011), the possibility of the central bank supplying funds to the financial intermediary is ignored.

them is the premium the banker earns on her assets. The banker's equity capital or net worth is defined as the difference between earnings on assets and interest payments on liabilities,

$$N_{j,t+1} = r^k_{t+1} q_t S_{j,t} - r_{t+1} b_{j,t} \overset{(9)}{=} \left(r^k_{t+1} - r_{t+1} \right) q_t S_{j,t} + r_{t+1} N_{j,t} \tag{10}$$

The banker's objective is to maximize expected future wealth, given by

$$\begin{aligned} V_{j,t} = maxE_t \left\{ \sum_{k=0}^{\infty} (1-\theta)\, \theta^k \beta^{k+1} \Lambda_{t,t+1+k} N_{j,t+1+k} \right\} \overset{(10)}{=} \\ maxE_t \left\{ \sum_{k=0}^{\infty} (1-\theta)\, \theta^k \beta^{k+1} \Lambda_{t,t+1+k} \left[\left(r^k_{t+1+k} - r_{t+1+k} \right) q_{t+k} S_{j,t+k} + r_{t+1+k} N_{j,t+k} \right] \right\} \end{aligned} \tag{11}$$

where $\Lambda_{t,t+1+k} = \frac{\lambda_{t,t+1+k}}{\lambda_t}$. When the discounted risk adjusted premium $\beta^k \Lambda_{t,t+k} \left(r^k_{t+1+k} - r_{t+1+k} \right)$ in any given period is positive, the financial intermediary gains from expanding her assets indefinitely, and she does so by borrowing additional funds from households. A moral hazard problem imposes a limit in this ability. More specifically, at the beginning of each period the banker can abscond with a fraction $\lambda^c \in (0,1)$ of the funds she manages. If she chooses to do so, the funds are transferred to the banker's respective household[17]. However, if the banker chooses this option there is a cost since depositors are assumed to be capable of forcing the financial intermediary into bankruptcy and recover the remaining fraction 1 - λ^c of assets. Thus, the banker j who chooses to do so, absconds with the $\lambda^c q_t S_{j,t}$ amount of funds. Therefore, households are willing to deposit funds to the banker, up to the point that the following incentive constraint is satisfied,

$$V_{j,t} \geq \lambda^c q_t S_{j,t} \tag{12}$$

where the LHS of inequality (12) denotes what the banker j loses if she chooses to abscond with a fraction of the bank's assets and the RHS what she gains from doing so. Condition (12) ensures that bankers will not divert funds in the equilibrium[18]. In equilibrium, the incentive constraint binds, implying that the bank's balance sheet is constrained by its net worth:

$$q_t S_t = \phi_t N_t \tag{13}$$

where $S_t = \int_{1-f}^{1} S_{j,t} dj$ denotes the aggregate quantity of intermediate assets; $N_t = \int_{1-f}^{1} N_{j,t} dj$ denotes aggregate financial intermediaries equity capital or net worth; and ϕ_t denotes the ratio of the privately intermediated assets to equity or in other words the private leverage ratio. Finally, after aggregating over existing and entering financial intermediaries, the aggregate net worth can be shown to evolve as[19]

$$N_t = \theta \left[\left(r^k_t - r_t \right) \phi_{t-1} + r_t \right] N_{t-1} + \omega^e q_t S_{t-1} \tag{14}$$

where $\omega^e q_t S_{t-1}$ are the aggregate transfers from the household towards entering bankers.

[17] As mentioned above, bankers are members of the representative household.

[18] In the online appendix we derive a recursive formulation for $V_{j,t}$

[19] A detailed derivation is presented in the online appendix.

3.2.2 Government Intermediation

The central bank can conduct credit policy by issuing government debt to households that pay the riskless rate r_{t+1}. Then, it lends the funds to intermediate good producers at the market lending rate r^k_{t+1}[20]. In this case, the total value of intermediated assets is given by the sum of public and private intermediated assets,

$$q_t S_t = q_t S_{p,t} + q_t S_{g,t} \tag{15}$$

where $q_t S_{g,t}$ denotes the total value of assets intermediated through government assistance and $q_t S_{p,t}$ denotes the total value of privately intermediated assets. We assume that government intermediation is not balance sheet constrained but it involves an efficiency cost of τ^u per unit supplied[21]. In addition, the central bank is assumed to fund only a fraction ψ^u_t of total intermediated assets,

$$q_t S_{g,t} = \psi^u_t q_t S_t \tag{16}$$

The central bank issues government bonds $b_{g,t}$ equal to $\psi^u_t q_t S_t$ to fund this activity. Then, the central bank's net earnings from intermediation in any given period t are equal to $\left(r^k_t - r_t\right) b_{g,t}$. These net earnings are a source of revenue for the government[22]. As illustrated in eq. (13) privately intermediated funds are constrained by financial intermediary's net worth, hence,

$$q_t S_t = \phi^c_t N_t \tag{17}$$

where $\phi^c_t = \frac{\phi_t}{1-\psi^u_t}$ is defined as the leverage ratio for total intermediated funds, indicating a positive relationship between ϕ^c_t and the intensity of government credit policy, ψ^u_t.

3.3 Production Side

3.3.1 Intermediate Good Producer

The representative intermediate good producing firm finances its capital acquisitions in each period by obtaining funds from financial intermediaries and from government, if government credit policy is applied. To do so, the intermediate firm first issues S_t claims equal to the number of units of capital acquired k_t and prices each claim at the price of a unit of capital q_t. Then, $q_t k_t$ denotes the acquired value of capital and $q_t S_t$ denotes the value of claims against this capital. Since arbitrage is possible it must hold that

$$q_t k_t = q_t S_t \tag{18}$$

where q_t is the price of both bonds and capital. It is assumed that there are no adjustment costs at the firm level; hence, the intermediate firm's capital choice can be treated as being static. When government credit policy is applied, S_t is given by the sum of public and private intermediated assets, $S_t = S_{g,t} + S_{p,t}$ and it holds that $\phi^c_t N_t = q_t k_t$. Each period t, the representative intermediate good producer produces output y^m_t according to a constant return to scale technology in capital k_{t-1}, bought from capital good producers and labor services n^d_t, rented by workers. In addition, the intermediate firm faces a constant productivity A. Then,

$$y^m_t = A\left(u^k_t \xi_t k_{t-1}\right)^\alpha \left(n^d_t\right)^{1-\alpha} \tag{19}$$

[20]In this scenario the real stock of bonds b_t in the household's budget constraint, eq. (2), denotes the sum of bonds issued by banks and government.

[21]According to Gertler & Karadi (2011), this deadweight loss could reflect the costs of raising funds via government debt or it might reflect costs to the central bank of identifying preferred private sector investments.

[22]The government's budget constraint when government credit policy is applied, is presented in section 3.4.

where u_t^k denotes the physical capital utilization rate; $\alpha \in (0,1)$ is the capital share and $1-\alpha$ is the labor share. The labor used by the intermediate firm, is defined as a labor index given by a constant elasticity of substitution (CES) aggregator[23]

$$n_t^d \equiv \left(\frac{1}{1-f}\right)^{\frac{1}{\epsilon_w}} \left(\int_0^{1-f} n_{j,t}^{\frac{\epsilon_w-1}{\epsilon_w}} dj\right)^{\frac{\epsilon_w}{\epsilon_w-1}} \tag{20}$$

where $n_{j,t}$ denotes the quantity of type j labor employed by the intermediate firm in period t.
After deciding optimally how much labor of each type j to employ, the intermediate good firm decides over capital utilization u_t^k and labor n_t^d, to maximize its real profits every single period t,

$$\max_{\{u_t^k, n_t^d\}_{t=0}^{\infty}} \Pi_t^{IFr} = mc_t A \left(u_t^k \xi_t k_{t-1}\right)^{\alpha} \left(n_t^d\right)^{1-\alpha} - r_t^k q_{t-1} k_{t-1} - w_t n_t^d + (q_t - \delta_t)\, \xi_t k_{t-1} \tag{21}$$

where mc_t denotes the price of intermediate good producer's output and has the interpretation of real marginal costs; δ_t denotes the quarterly capital depreciation rate and is a function of capital utilization u_t^k; and $(q_t - \delta_t)\,\xi_t k_{t-1}$ is the value of the underappreciated capital in period t, which is sold to capital good producers after production takes place[24].

3.3.2 Capital Good Producers

Capital goods producers are owned by households and operate in a perfectly competitive market. At the end of period t, the representative capital producer buys previous period unappreciated capital from intermediate good producers and then repairs this depreciated capital along with producing new capital[25]. After capital production and repairing, the capital good producer sells the new and repaired capital at price q_t. The market value of a unit of capital q_t is endogenously determined. We assume that there are no adjustment costs in repairing old capital, but there are flow adjustment costs associated with producing new capital. Since profits from selling used capital are zero, the discounted real profits of the representative capital good producer are given by

$$E_t \left\{ \sum_{k=0}^{\infty} \beta^k \Lambda_{t,t+k} \left[(q_{t+k} - 1)\, x_{t+k}^n - f\left(\frac{x_{t+k}^n + x}{x_{t+k-1}^n + x}\right) \left(x_{t+k}^n + x\right) \right] \right\} \tag{22}$$

where $\Lambda_{t,t+k} = \frac{\lambda_{t+k}}{\lambda_t}$ is the discount factor; net investment is defined as the gross capital created (investment) minus the quantity of repaired capital, $x_t^n \equiv x_t - \delta_t \xi_t k_{t-1}$; and $f\left(\frac{x_t^n + x}{x_{t-1}^n + x}\right)(x_t^n + x)$ are adjustment costs to net investment, with x denoting the steady state level of investment and $f(1) = f'(1) = 0$, $f''(\cdot) > 0$. The representative capital good producer chooses the period t net investment, x_t^n, to maximize eq. (22). The first order condition gives the following relation for net investment[26],

$$q_t = 1 + f_t(\cdot) + \frac{\partial f_t(\cdot)}{\partial x_t^n}(x_t^n + x) - \beta E_t \left\{ \Lambda_{t,t+1} \frac{\partial f_{t+1}(\cdot)}{\partial x_t^n} \left(x_{t+1}^n + x\right) \right\} \tag{23}$$

Finally, the law of motion for physical capital is given by

$$k_t = \xi_t k_{t-1} + x_t^n \tag{24}$$

[23] Following Del Negro et al. (2017), the labor aggregator is multiplied by the constant $\left(\frac{1}{1-f}\right)^{\frac{1}{\epsilon_w}}$, where $1-f$ is the fraction of workers in the representative household. This ensures that the demand for labor is equal to the average labor used under symmetry. Because there is no entry of new types of labor, it only simplifies the notation without affecting the model dynamics.

[24] The intermediate firm's maximization problem and the assumed functional form for capital depreciation are analytically presented in the online appendix.

[25] It is assumed that the cost of repairing old capital is equal to one. In addition, old capital after being repaired is indistinguishable from newly produced capital.

[26] The exact functional form for adjustment costs can be found in the online appendix.

3.3.3 Retail Goods Producers

The final stage of production consists of a continuum of monopolistically competitive retail goods firms indexed by i $\in$ [0,1]. Each retail good producer i buys intermediate good y_t^m at a price equal to the real marginal cost mc_t. Then she re-packages it to produce differentiated output $y_{i,t}$ at price $P_{i,t}$. Assuming that it takes one unit of intermediate good to produce one unit of retail good, the relative price of the intermediate good coincides with the real marginal cost mc_t. Final good y_t is given by aggregating retail goods $y_{i,t}$ using a CES aggregator,

$$y_t = \left(\int_0^1 y_{i,t}^{\frac{\epsilon_p - 1}{\epsilon_p}} \, di \right)^{\frac{\epsilon_p}{\epsilon_p - 1}} \tag{25}$$

where $\epsilon_p \in (1, +\infty)$ indicates the elasticity of substitution among retail goods. Each household member chooses the optimal allocation of consumption. Solving the cost minimization problems of all users of final output, gives the following sequence of demand functions for retail firm's i output,

$$y_{i,t} = \left(\frac{P_{i,t}}{P_t} \right)^{-\epsilon_p} y_t \tag{26}$$

As in Ascari (2004), Ascari & Sbordone (2014) and Yun (1986), a modified version of Calvo (1983) pricing setup is assumed. More specifically, in each period there is a fixed probability $1 - \theta_p$ that a retail firm can re-optimize its price. The optimal price set every period t is defined as $P_{i,t}^*$. With probability θ_p, instead, the retail firm automatically and without any cost adjusts its price according to an indexation rule that can depend on the previous period inflation rate and/or on the steady state inflation rate, $P_{i,t+k} = P_{i,t} \left(\bar{\pi}^{\chi k} \right)^{1-\mu} \left(\pi_{t-k,t+k-1}^{\chi} \right)^{\mu}$. Parameter $\chi \in [0, 1]$ allows for any degree of price indexation and $\mu \in [0, 1]$ allows for any combination of indexation between steady state inflation $\bar{\pi}$ and past inflation rates. Retail firms discount profits k periods into the future by $\beta^k \frac{\lambda_{t+k}^n}{\lambda_t^n} \theta_p^k$. Solving the dynamic problem of an updating retail firm gives the optimal price setting equation,

$$P_{i,t}^* = \frac{\epsilon_p}{\epsilon_p - 1} \frac{E_t \left\{ \sum_{k=0}^{\infty} \theta_p^k \beta^k \lambda_{t+k} mc_{t+k|t} \left[\frac{\left(\bar{\pi}^{\chi k} \right)^{1-\mu} \left(\pi_{t-k,t+k-1}^{\chi} \right)^{\mu}}{P_{t+k}} \right]^{-\epsilon_p} y_{t+k} \right\}}{E_t \left\{ \sum_{k=0}^{\infty} \theta_p^k \beta^k \lambda_{t+k} \left[\frac{\left(\bar{\pi}^{\chi k} \right)^{1-\mu} \left(\pi_{t-k,t+k-1}^{\chi} \right)^{\mu}}{P_{t+k}} \right]^{1-\epsilon_p} y_{t+k} \right\}} \tag{27}$$

3.4 Government

The government collects lump sum taxes to finance its constant real government spending $\bar{g}$. Given the government spending; lump-sum taxes adjust so as the government budget constraint holds with equality. The government budget constraint, in real terms, is given by

$$\tau_t^l = \bar{g} \tag{28}$$

On the other hand, when government intervention through credit policy is applied, the government budget constraint, is described by

$$\tau_t^l = \bar{g} - \left(r_t^k - r_t \right) \psi_{t-1}^u q_{t-1} k_{t-1} + \tau^u \psi_t^u q_t k_t \tag{29}$$

where $\left(r_t^k - r_t \right) \psi_{t-1}^u q_{t-1} k_{t-1}$ denotes government's profits from intermediation between households and intermediate good producers; and $\tau^u \psi_t^u q_t k_t$ denotes costs of raising funds through government debt.

3.5 Modeling Unemployment

Unemployment is modeled as in Galí (2011a), Galí (2011b) and Galí (2015). All households are considered identical, in the sense that they contain all different worker types. The representative household aims to maximize the whole household's welfare. As a result, it would not find it optimal to send a household member (j,s) to work if their real wage is lower than their disutility from work. Such an action would lead to welfare losses not only for the specific household member but also for the whole household since full consumption sharing within the household is assumed. Thus, the representative household chooses to send to work workers of type (j,s) whose real wage is equal or higher than their individual disutility from work expressed in consumption units,

$$\frac{W_{j,t}}{P_t} \geq \frac{\psi^n s^{\phi_n}}{\lambda_t} \tag{30}$$

Note that the LHS of inequality (30) is the real wage of j^{th} labor type and the RHS denotes her marginal rate of substitution between leisure and consumption, $MRS_{j,t}$. If the labor market was competitive, it would hold that

$$\frac{W_{j,t}}{P_t} = MRS_{j,t} = \frac{\psi^n L_{j,t}^{\phi_n}}{\lambda_t} \tag{31}$$

where $L_{j,t}$ denotes the total population of labor of type j in the economy[27]. In addition, $L_t = \int_0^{1-f} L_{j,t} dj$ can be interpreted as a measure of aggregate participation or the labor force in the model[28]. In the monopolistically competitive labor market model, the number of employees is always lower[29] than the number of workers in the labor force and the "gap" between them is determined by the wage markup. The wage markup pins down the long-run unemployment rate to a specific positive value. Then the existence of nominal wage frictions generates fluctuations in the wage markup, and consequently in the unemployment rate, in response to aggregate shocks. Finally, the workers' unemployment rate u_t is defined as the ratio of total unemployed workers to aggregate household participation in the labor force.

3.6 Monetary Policy and Exogenous Processes

3.6.1 Conventional Policy

Conventional monetary policy is conducted by a monetary authority which sets the nominal interest rate according to the following "simple"[30] Taylor Rule,

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left[\bar{i} + \Phi_\pi ln\left(\frac{\pi_t}{\bar{\pi}}\right) + \Phi_y ln\left(\frac{y_t}{y_{t-1}}\right)\right] + \epsilon_{v,t} \tag{32}$$

where $\bar{\pi}$ is the long-run target for inflation, $\bar{i}$ is the long-run nominal interest rate, parameter $\rho_i \in [0,1]$ determines the degree of monetary policy inertia, Φ_π is the policy response to price inflation, Φ_y is the policy response to the quarterly growth rate of output, and $\epsilon_{v,t} \overset{iid}{\sim} N(0, \sigma_v^2)$ is a monetary policy shock which is assumed to follow a white noise process with zero mean and $\sigma_v \in (0, +\infty)$ standard deviation.

According to policy rule (32), the monetary authority seeks to stabilize inflation and the growth rate of real output and at the same time allows for policy inertia. For values of ρ_i close to unity (as assumed in the simulations below), this "simple" interest rate rule is considered to be a good approximation to ECB's policy.

[27] $L_{j,t}$ denotes all workers of labor type j, either employed or unemployed.

[28] Integration is from 0 to 1 - f because not every household member is a worker.

[29] Since the wage markup is greater than unity.

[30] "Simple" in the sense that the nominal interest rate is set as a function of a small number of easily observable macroeconomic variables.

3.6.2 Government Credit Policy

When intermediating between households and intermediate good producers, the central bank adjusts credit ψ_t^u according to the following policy rule,

$$\psi_t^u = \bar{\psi}^u + \Phi_u E_t \left\{ ln \left(\frac{r_{t+1}^k / r_{t+1}}{\bar{r}^k / \bar{r}} \right) \right\} \tag{33}$$

where $\Phi_u \in [0, +\infty)$ is the unconventional policy response coefficient and $\bar{\psi}^u$ denotes the steady state fraction of publicly intermediated assets[31]. Policy rule (33) implies that the central bank increases credit when the premium $E_t \left\{ r_{t+1}^k / r_{t+1} \right\}$ increases relative to its steady state value $\bar{r}^k / \bar{r}$.

3.6.3 Exogenous Processes

Capital quality is determined by the exogenous state variable $\{\xi_t\}$, which is assumed to follow a logarithmic AR(1) process with drift,

$$ln \left(\frac{\xi_t}{\bar{\xi}} \right) = \rho_\xi ln \left(\frac{\xi_{t-1}}{\bar{\xi}} \right) - \epsilon_{\xi,t} \tag{34}$$

where $\rho_\xi \in [0, 1)$ is the persistence parameter and $\bar{\xi} \in [0, +\infty)$ denotes the long-run value of the exogenous variable. Moreover, the shock is assumed to follow a white noise process with zero mean and $\sigma_\xi \in (0, +\infty)$ standard deviation, $\epsilon_{\xi,t} \overset{iid}{\sim} N(0, \sigma_\xi^2)$.

3.7 Equilibrium and Aggregation

When government credit policy is applied, market clearing requires[32]

$$y_t = c_t + x_t + \bar{g} + \frac{\kappa}{2} \left(\frac{x_t^n + x}{x_{t-1}^n + x} - 1 \right)^2 (x_t^n + x) + \tau^u \psi_t^u q_t k_t \tag{35}$$

and when it is not

$$y_t = c_t + x_t + \bar{g} + \frac{\kappa}{2} \left(\frac{x_t^n + x}{x_{t-1}^n + x} - 1 \right)^2 (x_t^n + x) \tag{36}$$

where the last two terms on the RHS of eq. (35) denote total net investment adjustment costs in the economy and total costs of raising funds through government debt, respectively.

4 Quantitative Analysis

4.1 Calibration and Steady State

A zero inflation steady state is assumed by setting long-run inflation $\bar{\pi}$ equal to one. Then, standard Eurozone values are given to the model's parameters. More specifically, the long-run unemployment rate is set equal to the mean of period 1999Q1-2022Q4 aggregate unemployment rate series for the Eurozone, which is 9.2%. Then, keeping the value of labor demand elasticity ϵ_w = 4.3, as in Galí (2022) and Christoffel et al. (2008), it is possible to calibrate the value of elasticity ϕ_n at the zero inflation steady state, $(1 - 0.092)^{\phi_n} = \frac{4.3-1}{4.3} \Rightarrow \phi_n \approx 2.74$. Goods demand elasticity $\epsilon_p = 3.8$, as in Galí (2022). The rate of time preference parameter β is set equal to 0.994

[31]Note that for parameter values $\Phi_u = \tau^u = 0$, government intermediation is "switched off" and the model with government credit policy collapses to the conventional monetary policy model.

[32]In the online appendix we present analytical derivations of the model's aggregate conditions.

to match a 2.48% average annualized real interest rate for the Euro Area, as in Laureys et al. (2021). The share of government spending on real output ω^g is set equal to 0.222, which according to Laureys et al. (2021) is the average of government spending plus net exports as a proportion of the euro area GDP. As far as the degree of hysteresis is concerned a moderate value of 0.65 is considered, which is compatible with the European (un)employment persistence according to empirical evidence, see Alogoskoufis (2018).

Policy responses to output Φ_y and inflation Φ_π are set equal to the standard values of 0.5/4 and 1.5, respectively. In addition, a rather strong degree of monetary policy inertia, $\rho_i = 0.9$ is assumed as in Galí (2022). The persistence parameter for capital quality's AR(1) process is set equal to 0.66 and an one percent standard deviation innovation is assumed, as in Gertler & Karadi (2011).

Furthermore, following Laureys et al. (2021), we assume relatively low degrees of price χ and wage $\widetilde{\chi}$ indexation 0.032 and 0.227, respectively; whereas all indexation is to past prices and wages, meaning that $\mu = \widetilde{\mu} = 1$. Moreover, θ_p & θ_w parameters, which determine the degree of price and wage rigidities, are set equal to 0.80 and 0.65, respectively. Habit persistence b^c is set equal to 0.798.

The fraction of bankers within the household is set equal to 0.03, which implies a 3% total mass of bankers in the economy as in Meh & Moran (2010). The long-run value of the premium is set equal to 48 basis point for quarterly data, which corresponds to 1.93% annualized rate average of investment-grade spreads, as in Laureys et al. (2021). As far as the physical capital depreciation parameters are concerned, u^k is set equal to one which means that all physical capital is used for production in the long-run. In addition, δ_2 is set equal to 0.799 as in Laureys et al. (2021) and the quarterly rate of capital depreciation $\bar{\delta}$ is set equal to 0.025 as in Gertler & Karadi (2011).

Turning to the model's financial sector, the long-run leverage ratio $\bar{\phi}$ is set equal to 4 as in Gertler & Karadi (2011) and the banker's survival probability θ is set equal to 0.940, which corresponds to an average lifetime of 16 quarters, as in Laureys et al. (2021). We assume that in the long-run there are no publicly intermediated assets, i.e., $\bar{\psi}^u = 0$ as in Gertler & Karadi (2011). Unless otherwise noted, unconventional monetary policy is "switched off" by setting the central bank's credit efficiency cost τ^u and the credit policy intermediation intensity Φ_u equal to zero. Finally, we assume that the union's long-run employment target, $\bar{n}^*$, is equal to the natural level of employment from the standard Calvo wages version of the model[33]. Table 3 summarizes our calibration.

[33]Note that this assumption does not affect the model's dynamics. However, it is a convenient assumption, since in this case both models share the same steady state. This steady state is reported in the online appendix.

β = 0.994	2.48% average annualized real interest rate, Laureys et al. (2021)
σ = 1	Logarithmic preferences in consumption
ϕ_n = 2.74	9.2% average unemployment rate
α = 0.25	Galí (2022)
ϵ_p = 3.8	Galí (2022)
ϵ_w = 4.3	Galí (2022) and Christoffel et al. (2008)
θ_p = 0.80	Laureys et al. (2021)
θ_w = 0.65	Laureys et al. (2021)
χ = 0.032	Laureys et al. (2021)
$\widetilde{\chi}$ = 0.227	Laureys et al. (2021)
b^c = 0.798	Laureys et al. (2021)
ψ^n = 1	Galí (2022)
θ = 0.940	Average lifetime of 16 quarters, Laureys et al. (2021)
f = 0.03	3% total mass of bankers in the economy, Meh & Moran (2010)
δ_2 = 0.799	Laureys et al. (2021)
n^* = 0.8781	Calvo wages model
Φ_y = 0.125	0.5 divided by 4 (for quarterly calibration)
Φ_π = 1.5	Standard value for the policy response to inflation
κ = 1.456	Laureys et al. (2021)
ρ_i = 0.90	Galí (2022)
ρ_ξ = 0.66	Gertler & Karadi (2011)
ω^g = 0.222	Average of government spending plus net exports as a proportion of GDP, Laureys et al. (2021)
$\bar{\delta}$ = 0.025	Gertler & Karadi (2011)
$pr\bar{e}m$ = 1.0048	1.93% annualized rate, average of investment-grade spreads, Laureys et al. (2021)
$\bar{\phi}$ = 4	Gertler & Karadi (2011)
γ = 0.65	Alogoskoufis (2018)
τ^u = 0 or 0.001	Gertler & Karadi (2011)
$\bar{\psi}^u$ = 0	Gertler & Karadi (2011)

Table 3: Calibration

The model's dynamics are derived by linearizing all relevant equations around the non-stochastic zero inflation steady state and then using standard methods of numerical simulations.

4.2 The Effects of Employment Hysteresis on the Propagation of Aggregate Shocks

This section presents the model's transitional dynamics after a monetary policy shock or a capital quality shock. The monetary authority is assumed to follow the "simple" Taylor rule, eq. (32), that stabilizes price inflation and the quarterly growth rate of real output. Figures 2 - 5 summarize the dynamic responses of key macroeconomic variables; expressed as percentage deviations from the deterministic steady state. To highlight the role of hysteresis, we compare the dynamics of the Insiders-Outsiders model, depicted by the blue lines, to those of an otherwise identical Calvo wages version of model, depicted by the pink lines.

4.2.1 Monetary Policy Shock

Figures 2 and 3 present the effects of a monetary contraction as a 1% unexpected increase in the short-term nominal interest rate. We can see that real output, employment and inflation all decrease on impact, whereas the unemployment rate increases. In the presence of hysteresis, the response of inflation turns positive relatively faster, this is attributed to the more modest response of (nominal) wages which causes inflationary pressures. In addition, the increase in unemployment is 50% stronger and 2.5 times more persistent relative to the Calvo wages version of the model. Similar results hold for the responses of real output and employment.

Dynamic responses after a monetary policy shock, expressed as percentage deviations from steady state, $\rho_i = 0.90$, σ_υ = 1%. Policy response coefficients $\Phi_\pi = 1.5$, $\Phi_y = 0.5/4$.

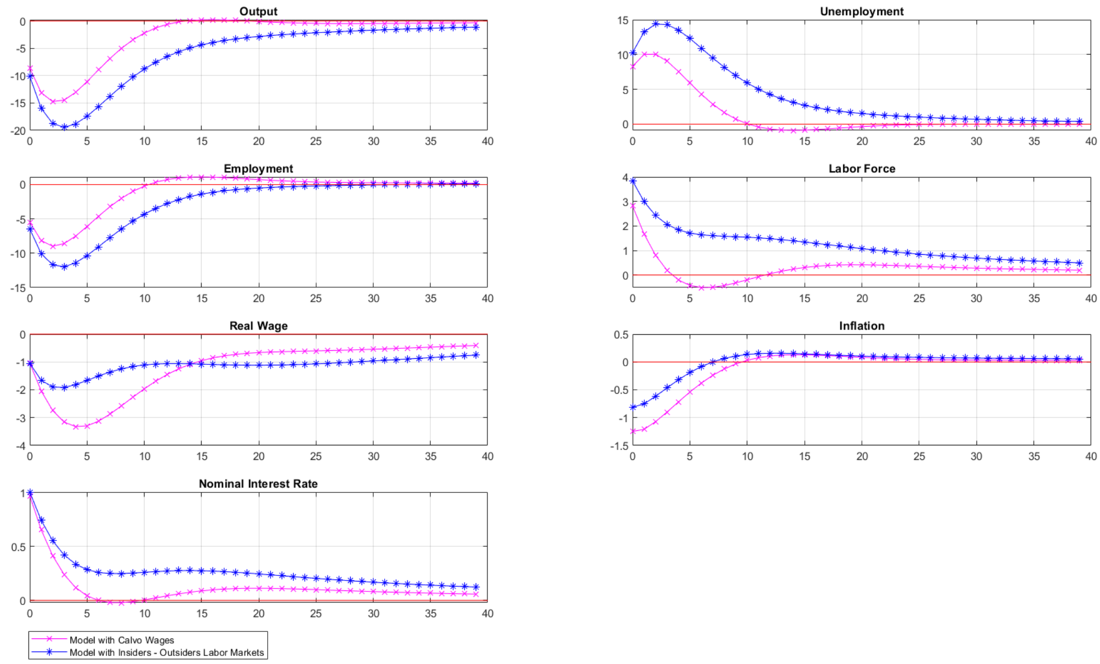


Figure 2: Dynamic Responses after a Monetary Policy Shock

Financial frictions amplify the effects of a monetary policy shock. This is attributed to monetary policy which has a relatively large effect on investment (drops around 15%) and asset prices (price of capital in Figure 3) that drop around 25%, triggering by this way the model's "financial accelerator" mechanism.

Dynamic responses after a monetary policy shock, expressed as percentage deviations from steady state, $\rho_i = 0.90$, σ_υ = 1%. Policy response coefficients $\Phi_\pi = 1.5$, $\Phi_y = 0.5/4$.

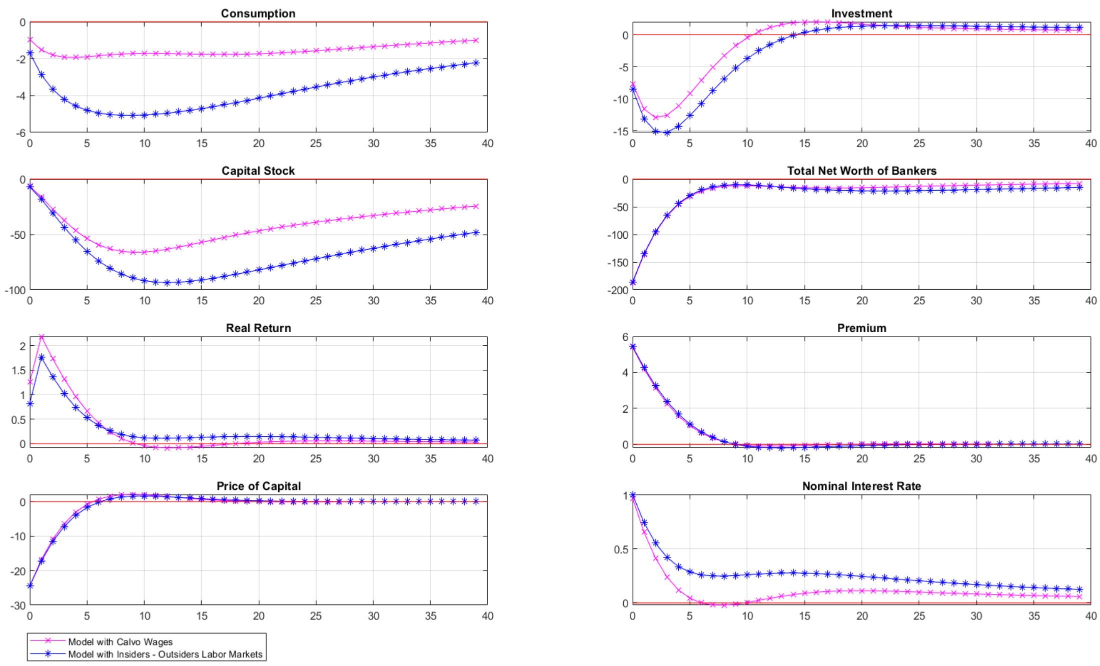


Figure 3: Dynamic responses after a Monetary Policy Shock (cont.)

4.2.2 Capital Quality Shock

Figures 4 & 5 present the effects of a 1% unexpected decrease in capital quality. A negative capital quality shock lessens the quantity of financial intermediaries' assets and leads to an enhanced decline in their net worth, due to their high degree of leverage.

Quantitative results indicate that an unexpected drop in capital quality causes a strong decline in real output. The unemployment rate increases on impact. The central bank initially decreases the nominal interest rate as a policy response to the drop in real output but then it increases it since it is more concentrated on stabilizing the inflation rate, which exhibits a lagged increase. Employment decreases more in the hysteresis model due to the more modest drop in workers' wages. This, combined with an enhanced increase in the labor force causes a stronger and more persistent increase in the unemployment rate. In the hysteresis model, the recession is much stronger, around 3% in its peak relative to 2.2% in the Calvo wages model. It is also 3 times more persistent. Hence, hysteresis significantly amplifies the impact of a capital quality shock in the economy.

The effects of a capital quality shock take place in two stages. Firstly, following an unexpected drop in capital quality the stock of physical capital declines; this initial decline reduces asset values by reducing the effective quantity of physical capital. Then there is a second effect, due to the leverage ratio constraint; the weakening of the financial intermediaries' balance sheets (decline in their net worth N_t) induces a decline in asset demand which reduces assets prices (the price of capital q_t) and investment x_t. This endogenous drop in asset prices shrinks further financial intermediaries' balance sheets. Thus, the overall contraction is enhanced by the degree of leverage.

Dynamic responses after an unexpected drop in capital quality, expressed as percentage deviations from steady state, $\rho_\xi = 0.66$, σ_ξ = 1%. Policy response coefficients $\Phi_\pi = 1.5$, $\Phi_y = 0.5/4$.

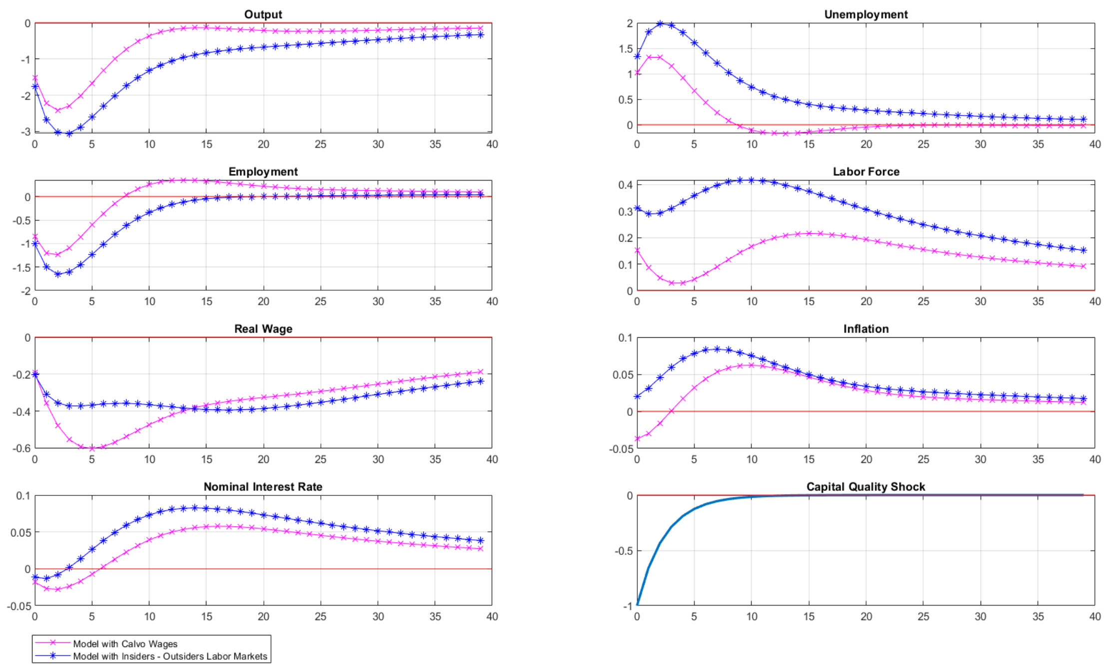


Figure 4: Dynamic Responses after a Capital Quality Shock

As it is apparent and from Figure 5, the drop in the financial intermediary's net worth causes an increase in the spread between the expected return on its assets (r_t^k) and the riskless rate (r_t). In other words, the premium increases. This pushes both investment and real output to decline. A capital quality shock is a financial shock which, according to Gertler & Karadi (2011), can mimic the results of a financial crisis, such as the one of 2008. For the rest of the paper, we concentrate on the effects of this shock.

Dynamic responses after an unexpected drop in capital quality, expressed as percentage deviations from steady state, $\rho_\xi = 0.66$, $\sigma_\xi = 1\%$. Policy response coefficients $\Phi_\pi = 1.5$, $\Phi_y = 0.5/4$.

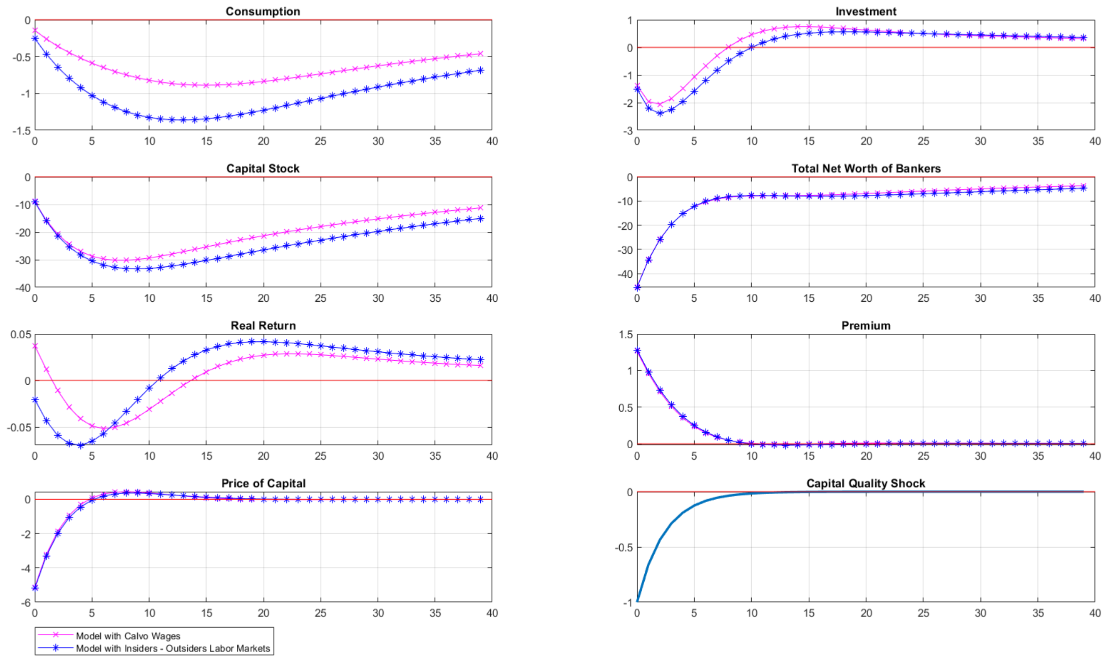


Figure 5: Dynamic Responses after a Capital Quality Shock (cont.)

4.3 Wage Inflation Stabilization

In the previous section, we showed that employment hysteresis tends to amplify recessions. This fact may be attributed to the "simple" Taylor rule which makes monetary policy to be mostly concentrated on stabilizing price inflation and less determined towards stabilizing employment. In the insiders-outsiders model, a trade-off arises due to the strong nominal wage sluggishness caused by employment hysteresis. This leads to inflationary or deflationary pressures that tend to mitigate the response of the nominal interest rate. This in turn causes stronger and more prolonged drops in real output along with stronger and more persistent increases in the unemployment rate.

To investigate this scenario, we consider a policy rule that seeks to stabilize wage inflation[34] and compare the results with the previous findings. More specifically, the monetary authority is assumed to apply conventional monetary policy according to the following rule:

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left[\bar{i} + \Phi_\pi ln\left(\frac{\pi_t}{\bar{\pi}}\right) + \Phi_y ln\left(\frac{y_t}{y_{t-1}}\right) + \Phi_w ln\left(\frac{w_t}{w_{t-1}}\frac{\pi_t}{\bar{\pi}}\right)\right] + \epsilon_{v,t} \quad (37)$$

Policy Rule	ρ_i	Φ_π	Φ_y	Φ_w
Standard Taylor rule	0.90	1.5	0.5/4	0
Output growth & wage inflation targeting rule	0.90	0	0.5/4	1.5

Table 4: Policy Parameters

We examine two monetary policy scenarios, as indicated in Table 4. The standard Taylor rule which as we saw earlier targets the quarterly growth rate of real output along with price inflation and, a policy rule that instead of

[34] or equivalently employment, as shown in Galí (2022).

price inflation targets wage inflation[35].

Dynamic responses after an unexpected drop in capital quality, expressed as percentage deviations from steady state, $\rho_\xi = 0.66$, σ_ξ = 1%. Policy response coefficients $\Phi_y = 0.5/4$ and $\Phi_\pi = 1.5$ & $\Phi_w = 0$ or $\Phi_\pi = 0$ & $\Phi_w = 1.5$.

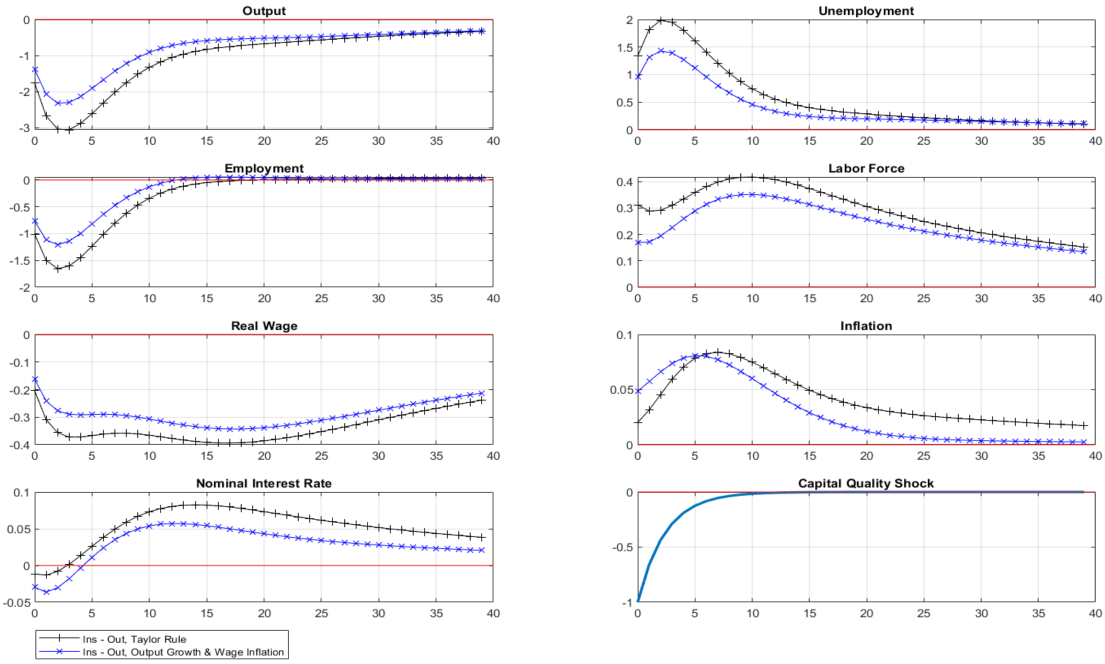


Figure 6: Comparison of “Simple” Taylor Rules - Capital Quality Shock

From Figures 6 & 7, we can see that a policy rule which targets the quarterly growth rate of output along with wage inflation, depicted by the blue lines, performs better than the standard Taylor rule policy which is depicted by the black lines.

In the hysteresis model, the change in employment is the only driving force of wage inflation. Thus, a Taylor policy which targets wage inflation manages a better stabilization of employment. This result is in line with the findings in Galí (2022) who examines various non-financial demand and supply shocks in the context of a baseline three equation New Keynesian model.

[35] Note that by setting the policy response to wage inflation Φ_w equal to zero in policy rule (37), it reduces to the standard Taylor rule (32).

Dynamic responses after an unexpected drop in capital quality, expressed as percentage deviations from steady state, $\rho_\xi = 0.66$, σ_ξ = 1%. Policy response coefficients $\Phi_y = 0.5/4$ and $\Phi_\pi = 1.5$ & $\Phi_w = 0$ or $\Phi_\pi = 0$ & $\Phi_w = 1.5$.

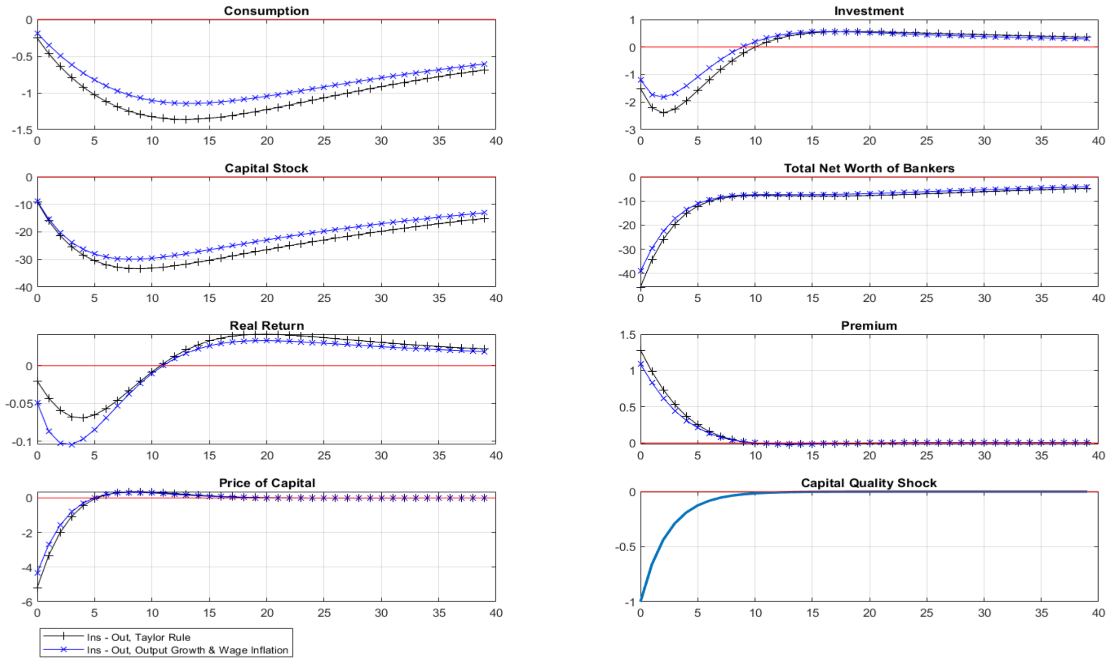


Figure 7: Comparison of “Simple” Taylor Rules - Capital Quality Shock (cont.)

4.4 Unconventional Monetary Policy

In this section we consider the role of credit interventions by the central bank in moderating a financial crisis. For this experiment, we assume that the central bank conducts both conventional and unconventional monetary policies. Conventional policy is applied according to the standard “simple” Taylor Rule described by eq. (32). In addition, at the onset of a crisis, which we define as a period where credit spreads rise sharply, the central bank injects credit in response to movements in credit spreads, according to feedback policy rule (33).

Figures 8 & 9 consider two different intervention intensities. In the first case, the feedback parameter Φ_u in the policy rule (33) equals 10, which is considered a moderate intervention. The blue line portrays this case. In the second case, the feedback parameter is raised to 97.248, which increases the intensity of the response, bringing it to the optimum (as we show in section 4.5.2). The green line portrays this case. For comparison, the black line portrays the case with no credit market intervention (or the standard Taylor rule case). We observe that in each case, credit policy significantly moderates the contraction.

Dynamic responses after an unexpected drop in capital quality, expressed as percentage deviations from steady state, $\rho_\xi = 0.66$, $\sigma_\xi = 1\%$. Taylor rule policy coefficients $\Phi_\pi = 1.5$, $\Phi_y = 0.5/4$.

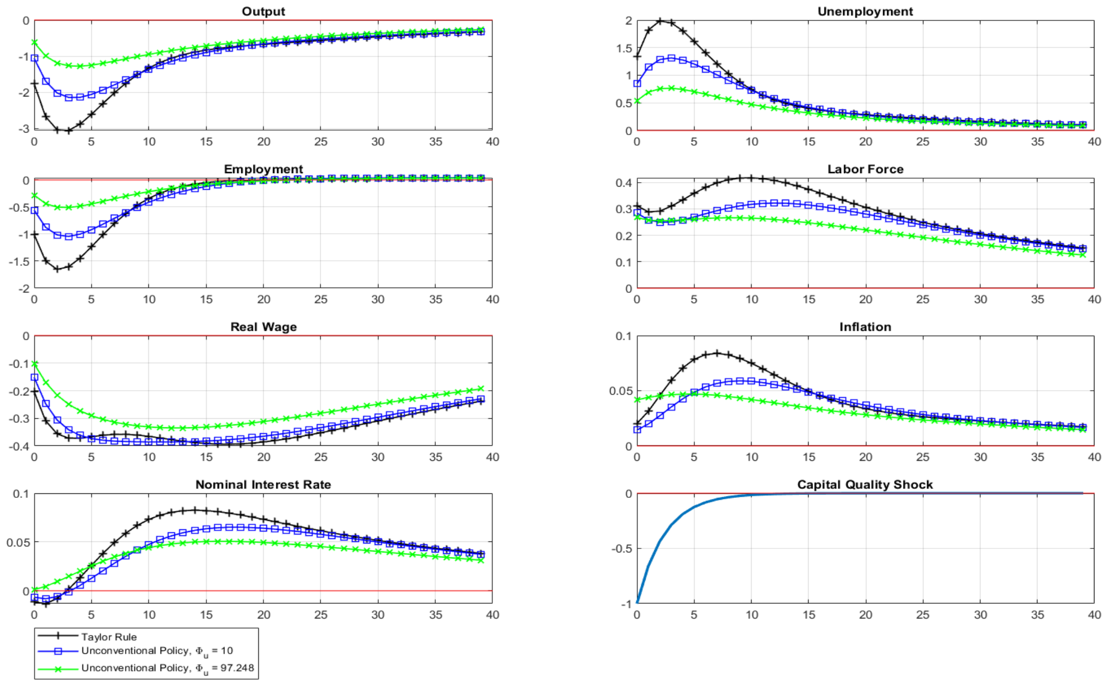


Figure 8: Unconventional Policy - Capital Quality Shock

Dynamic responses after an unexpected drop in capital quality, expressed as percentage deviations from steady state, $\rho_\xi = 0.66$, $\sigma_\xi = 1\%$. Taylor rule policy coefficients $\Phi_\pi = 1.5$, $\Phi_y = 0.5/4$.

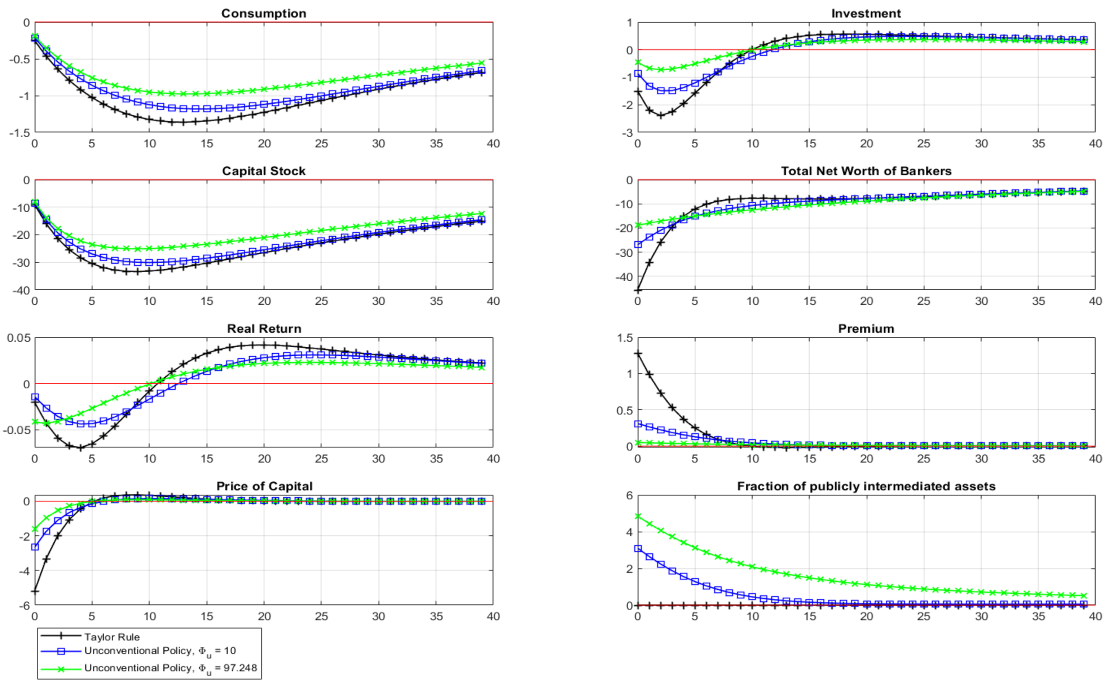


Figure 9: Unconventional Policy - Capital Quality Shock (cont.)

The prime reason for the moderation of the contraction is that the central bank's intermediation dampens the rise in the spread, which in turn dampens the decline in investment. The moderate intervention produces an increase in the central bank's balance sheet equal to approximately 3% of the value of the capital stock. The optimal intervention further moderates the decline by substantially moderating the rise in the spread. Doing so, however, requires that central bank lending increase to approximately 5% of the capital stock. This result is in accordance with the empirical studies of Borio & Zabai (2018) and Lenza et al. (2010), who show that unconventional monetary policies have led to significant expansions in the balance sheets of central banks.

Two additional points merit consideration; firstly, in each instance the central bank exits from its balance sheet slowly over time. In the case of the moderate intervention the process takes roughly 3 years (12 quarters). It takes roughly 3 times longer in the case of the optimal intervention. Secondly, despite the large increase in the central bank's balance sheet in response to the crisis, inflation does not exhibit any significant increase (less than 0.06%). The reduction in credit spreads induced by the policy provides sufficient stimulus to prevent deflation, but not enough to cause high inflation. This characteristic of the model is in line with the empirical findings in Elbourne et al. (2018) who find economically insignificant effects of ECB's unconventional monetary policy on the aggregate euro area inflation.

4.5 Welfare Analysis

Welfare is defined as the present discounted value of the flow utility of the representative household. A recursive representation of welfare can be expressed as

$$V_t = \mathbb{U}\left(c_t, n_{j,t}\right) + \beta E_t \left\{V_{t+1}\right\} \tag{38}$$

Welfare is computed by applying a second order approximation around the non-stochastic zero inflation steady state and then calculating the approximated theoretical moments. To make the different units of welfare comparable, we express the expected (mean) values of welfare under different policies into differences in "consumption equivalent" units[36]. Assuming log preferences in consumption, it is possible to derive the following expression,

$$\lambda^V = \exp\left[(1-\beta)\left(E\left\{V_t^F\right\} - E\left\{V_t^I\right\}\right)\right] - 1 \tag{39}$$

where λ^V denotes the fraction of consumption one would be willing to give up in each period in the baseline economy "I" to enjoy the same level of welfare as in the alternative economy "F"[37].

4.5.1 Welfare Analysis of Different Monetary Policy Rules

In this section, we perform a welfare exercise by examining quantitatively the welfare losses under four different conventional monetary policy scenarios, as indicated in Table 5. We assume that the monetary authority follows the "simple" monetary policy rule (37).

Policy Rule	ρ_i	Φ_π	Φ_y	Φ_w
Standard Taylor rule	0.90	1.5	0.5/4	0
Price inflation targeting rule	0.90	1.5	0	0
Wage inflation targeting rule	0.90	0	0	1.5
Output growth & wage inflation targeting rule	0.90	0	0.5/4	1.5

Table 5: Policy Parameters

Moreover, it is assumed that the long-run employment target for the labor union is equal to the efficient level of employment[38]. Figure 10 presents the welfare losses under the four different policy rules, as a function of hysteresis after a 1% negative capital quality shock. We can see that for high degrees of hysteresis, policy rules

[36] How much consumption would one be willing to give up (in each period) under one policy to enjoy the same level of welfare as under a different policy.

[37] If the baseline economy "I" has higher welfare relative to economy "F" the term inside the exp is negative, which means that $\lambda^V < 0$. In other words, someone must give up consumption in the high welfare economy "I".

[38] The long-run efficient level of employment is defined as the frictionless steady state employment and as shown in the online appendix,

that target wage inflation achieve less welfare losses (light blue and green lines). In addition, the benefits from implementing such policies increase with the degree of hysteresis.

As explained in section 4.3, a Taylor rule that targets the growth rate of output along with price inflation fails to adequately stabilize employment. This happens because in the insiders-outsiders model the nominal wage adjusts more sluggishly as hysteresis increases, as a result the persistence of employment increases. After aggregate shocks that cause a strong initial change in employment like a capital quality shock this effect is quite strong. Thus, the more modest welfare losses under policy rules which target wage inflation.

"Consumption equivalent" welfare losses across policies as a function of hysteresis (welfare losses are normalized to be equal to zero under the Taylor rule and in the absence of hysteresis).

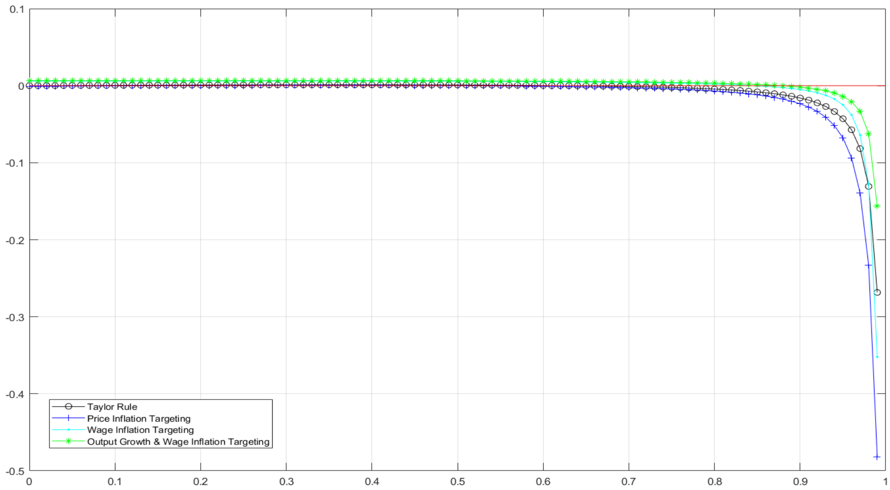


Figure 10: Welfare Comparisons - Capital Quality Shock

4.5.2 Welfare and Optimal Credit Policy

As a final exercise we use numerical methods to calculate the optimal degree of credit policy intervention, i.e., the value of Φ_u that fully stabilizes welfare after a financial shock. The optimal value of the policy response coefficient we find is $\Phi_u = 97.248$.

We compute welfare under the standard Taylor rule, the growth rate of output & wage inflation targeting rule, and the optimal credit policy rule, after a negative capital quality shock ranging from 0 to 15%. Then we express welfare in "consumption equivalent" units. Finally, we normalize these units to be equal to zero in the absence of exogenous shocks.

Figure 11 displays the welfare losses under the three policy rules: the standard Taylor rule (black line), the growth rate of output & wage inflation targeting rule (blue line) and the optimal credit policy rule (green line), as a function of the shock's magnitude.

Results indicate that under the optimal credit policy there are no welfare losses irrespective of the shock's magnitude. In addition, for relatively small shocks, less than 1%, there are no apparent welfare benefits for the central bank to use unconventional monetary policies. However, as the shock's magnitude increases over 1%, possibly leading the economy to a severe financial crisis, the welfare benefits from using credit policy to stabilize the economy start to appear. We notice that the welfare benefits from implementing such policies increase with the

is given by

$$n^e = \left[\frac{\frac{q}{\beta} - \left(q - \bar{\delta}\right)\bar{\xi}}{\alpha} \left(1 - \omega^g\right) - 1 + \left(1 - \bar{\delta}\right)\bar{\xi} \right]^{-\frac{\sigma}{\phi_n + \sigma}} \left(\left[\alpha A \left(\bar{\xi} u^k\right)^{\alpha}\right]^{\frac{1-\sigma}{1-\alpha}} \left[\frac{q}{\beta} - \left(q - \bar{\delta}\right)\bar{\xi}\right]^{\frac{\sigma - \alpha}{1-\alpha}} \frac{1-\alpha}{\alpha} \frac{1}{\psi^n} \frac{1 - \beta b^c}{\left(1 - b^c\right)^{\sigma}} \right)^{\frac{1}{\phi_n + \sigma}}$$

shock's magnitude. In fact, for a shock of 15%, not using credit policy implies losses around 90% under the standard Taylor rule or around 62% under the wage inflation targeting rule. This result is aligned with the findings in Cúrdia & Woodford (2011) who show that it is possible for disturbances originating in the financial sector to create circumstances under which central-bank lending to the private sector increases welfare. Other studies who find similar results include Chen et al. (2012), Harrison (2012) and Cúrdia & Woodford (2009).

"Consumption equivalent" welfare losses across policies as a function of the shock's magnitude (welfare losses are normalized to be equal to zero in the absence of exogenous shocks).

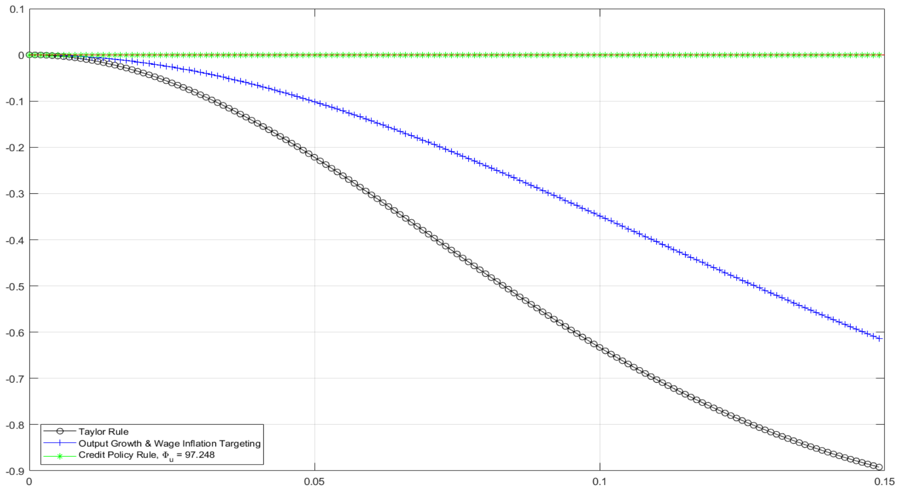


Figure 11: Optimal Credit Policy - Capital Quality Shock

Finally, we numerically calculate the degree of credit intervention that is necessary to achieve the same level of welfare as under the wage inflation targeting rule. We find the value of the policy response coefficient to be quite high $\Phi_u = 18.945$. Figure 12 presents the results. This last finding stresses the benefits of wage inflation targeting for an economy that is characterized by a significant degree of employment hysteresis.

"Consumption equivalent" welfare losses across policies as a function of the shock's magnitude (welfare losses are normalized to be equal to zero in the absence of exogenous shocks).

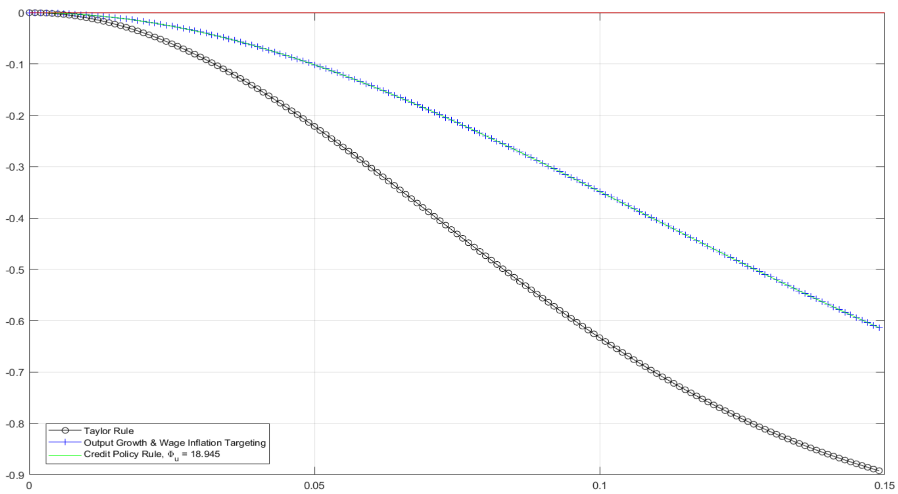


Figure 12: Wage Inflation Targeting Equivalent Credit Policy - Capital Quality Shock

5 Conclusions

Motivated by the high persistence of European unemployment that is apparent in the data, we have developed a medium-scale DSGE model that can explain this persistence. The model features endogenously determined constraints on the balance sheets of financial intermediaries. Within this framework, financial frictions arise due to an agency problem in the supply of credit. As far as the labor market of the model is concerned, two variations are considered. A standard Calvo wage setting (as a benchmark case) and a labor market structured in an insiders-outsiders fashion, where a labor union (for each labor type) can unilaterally set workers' wages to ensure employment for those already employed according to a hysteresis equation. Standard Eurozone parameter values are given to the model's parameters.

Quantitative results show that the model generates strong endogenous persistence after either a monetary policy shock or a financial shock. Both shocks are considered relevant to the onset of financial crises. More specifically, impulse response analysis shows that employment hysteresis significantly enhances the impact of aggregate shocks on unemployment, real output, and the rest of the examined macroeconomic aggregates.

In addition, welfare analysis reveals that a monetary policy rule that stabilizes wage inflation rather than price inflation leads to lower welfare losses. The relative gains from such policy appear to increase with the degree of hysteresis [39]. This finding has direct policy implications. Since, as we show, the European unemployment is characterized by a high degree of persistence, a change of policy towards wage inflation stabilization, potentially could help towards a faster stabilization of the European economy after a severe financial crisis.

Finally, unconventional policy through government interventions in credit is considered. After a negative capital shock, the use of government credit stabilizes the economy more effectively relative to standard monetary policy. In addition, more effective stabilization implies significantly higher welfare. These welfare gains are shown to increase with the financial shock's magnitude.

6 Acknowledgments

I am grateful for comments and helpful suggestions to Eleftherios Zacharias, as well as to the participants of the 7th International Conference on Applied Theory, Macro and Empirical Finance (AMEF 2023) and to the participants of the 21st Conference on Research on Economic Theory and Econometrics (CRETE 2023). I am responsible for any remaining errors.

7 Supplementary data

An appendix with analytical derivations and technical details related to this article can be found online.

References

Alogoskoufis George, 2018, "The Clash of Central Bankers with Labor Market Insiders, and the Persistence of Inflation and Unemployment", *Economica*, 85(337), pp. 152-176.

Alogoskoufis George, 2019, *Dynamic Macroeconomics*, MIT Press.

Ascari Guido, 2004, "Staggered Prices and Trend Inflation: Some Nuisances", *Review of Economic Dynamics*, 7(3), pp. 642-667.

[39] Galí (2022) finds similar results, using a textbook three equation New Keynesian model of hysteresis, he shows that optimal monetary policy calls for a strong emphasis on employment (or equivalently wage inflation) stabilization.

Ascari Guido & Sbordone Argia, 2014, “The Macroeconomics of Trend Inflation”, *Journal of Economic Literature*, 52(3), pp. 679-739.

Ball Laurence, 2014, “Long-Term Damage from the Great Recession in OECD Countries”, *NBER Working Paper No. 20185*.

Bernanke Ben & Gertler Mark, 1989, “Agency Costs, Net Worth, and Business Fluctuations”, *American Economic Review*, 79(1), pp. 14-31.

Bernanke Ben & Gertler Mark, 1990, “Financial Fragility and Economic Performance”, *The Quarterly Journal of Economics*, 105(1), pp. 87-114.

Bernanke Ben & Gertler Mark & Gilchrist Simon, 1999, “The Financial Accelerator in a Quantitative Business Cycle Framework”, *Handbook of Macroeconomics*, in: J. B. Taylor & M. Woodford (ed.), 1(21), pp. 1341-1393.

Blanchard Olivier & Summers Lawrence, 1986, “Hysteresis and the European Unemployment Problem”, *NBER Working Paper No. 1950*.

Bluedorn John & Leigh Daniel, 2018, “Is the Cycle the Trend? Evidence from the Views of International Forecasters”, *IMF Working Paper 18/163*.

Bluedorn John & Leigh Daniel, 2019, “Hysteresis in Labor Markets? Evidence from Professional Long-Term Forecasts”, *IMF Working Paper 19/114*.

Boeckx Jef & Dossche Maarten & Peersman Gert, 2017, “Effectiveness and Transmission of the ECB’s Balance Sheet Policies”, *International Journal of Central Banking*, 13(1), pp. 297-333.

Borio Claudio & Zabai Anna, 2018, “Unconventional monetary policies: a re-appraisal”, *Research Handbook on Central Banking*, in: Conti-Brown Peter & Lastra Rosa (ed.), 20, pp. 398-444.

Brunnermeier Markus & Eisenbach Thomas & Sannikov Yuliy, 2012, “Macroeconomics with Financial Frictions: A Survey”, *NBER Working Paper No. 18102*.

Burriel Pablo & Galesi Alessandro, 2018, “Uncovering the heterogeneous effects of ECB unconventional monetary policies across euro area countries”, *European Economic Review*, 101(C), pp. 210-229.

Calvo Guillermo, 1983, “Staggered prices in a utility-maximizing framework”, *Journal of Monetary Economics*, 12(3), pp. 383-398.

Cerra Valerie & Fatás Antonio & Saxena Sweta-Chaman, 2020, “Hysteresis and Business Cycles”, *IMF Working Paper 2020/073*.

Cerra Valerie & Saxena Sweta, 2000, “Alternative Methods of Estimating Potential Output and the Output Gap: An Application to Sweden”, *IMF Working Paper 00/59*.

Chari Varadarajan & Kehoe Patrick & McGrattan Ellen, 2009, “New Keynesian Models: Not Yet Useful for Policy Analysis”, *American Economic Journal: Macroeconomics*, 1(1), pp. 242-266.

Chen Han & Cúrdia Vasco & Ferrero Andrea, 2012, “The Macroeconomic Effects of Largescale Asset Purchase Programmes”, *Economic Journal*, 122(564), pp. 289-315.

Christiano Lawrence & Eichenbaum Martin & Evans Charles, 2005, “Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy”, *Journal of Political Economy*, 113(1), pp. 1-45.

Christiano Lawrence & Eichenbaum Martin & Trabandt Mathias, 2018, "On DSGE Models", *NBER Working Paper No. 24811*.

Christoffel Kai & Coenen Gnter & Warne Anders, 2008, "The new area-wide model of the euro area: a micro-founded open-economy model for forecasting and policy analysis", ECB Working Paper No. 944.

Claessens Stijn & Kose Ayhan & Terrones Marco, 2012, "How do business and financial cycles interact?", *Journal of International Economics*, 87(1), pp. 178-90.

Clark Kim & Summers Lawrence, 1982, "Labour Force Participation: Timing and Persistence", *Review of Economic Studies*, 49(5), pp. 825-844.

Cúrdia Vasco & Woodford Michael, 2009, "Conventional and Unconventional Monetary Policy", Federal Reserve Bank of New York Staff Report No. 404.

Cúrdia Vasco & Woodford Michael, 2010, "Credit Spreads and Monetary Policy", *Journal of Money, Credit and Banking*, 42(s1), pp. 3-35.

Cúrdia Vasco & Woodford Michael, 2011, "The central-bank balance sheet as an instrument of monetary policy", *Journal of Monetary Economics*, 58(1), pp. 54-79.

Del Negro Marco & Eggertsson Gauti & Ferrero Andrea & Kiyotaki Nobuhiro, 2017, "The Great Escape? A Quantitative Evaluation of the Fed's Liquidity Facilities", *American Economic Review*, 107(3), pp. 824-857.

Elbourne Adam & Ji Kan & Duijndam Sem, 2018, "The effects of unconventional monetary policy in the euro area", *CPB Netherlands Bureau for Economic Policy Analysis Working Paper No. 371*.

Ellwood David, 1982, "Teenage Unemployment: Permanent Scars or Temporary Blemishes?", *The youth labor market problem: Its nature, causes, and consequences*, University of Chicago Press, pp. 349-390.

Ferdinandusse Marien & Freier Maximilian & Ristiniemi Annukka, 2020, "Quantitative easing and the price-liquidity trade-off", *ECB Working Paper No. 2399*.

Galí Jordi, 2011a, "The Return Of The Wage Phillips Curve", *Journal of the European Economic Association*, 9(3), pp. 436-461.

Galí Jordi, 2011b, *Unemployment Fluctuations and Stabilization Policies: A New Keynesian Perspective*, The MIT Press.

Galí Jordi, 2015, "Hysteresis and the European Unemployment Problem Revisited", *NBER Working Paper No. 21430*.

Galí Jordi, 2018, "The State of New Keynesian Economics: A Partial Assessment", *NBER Working Paper No. 24845*.

Galí Jordi, 2022, "Insider - Outsider Labor Markets, Hysteresis and Monetary policy", *Journal of Money, Credit and Banking*, 54(1), pp. 53-88.

Gambacorta Leonardo & Hofmann Boris & Peersman Gert, 2014, "The Effectiveness of Unconventional Monetary Policy at the Zero Lower Bound: A CrossCountry Analysis", *Journal of Money, Credit and Banking*, 46(4), pp. 615-642.

Gertler Mark & Gilchrist Simon, 2018, "What Happened: Financial Factors in the Great Recession", *NBER Working Paper No. 24746*.

Gertler Mark & Karadi Peter, 2011, "A Model of Unconventional Monetary Policy", *Journal of Monetary Economics*, 58(1), pp. 17-34.

Gertler Mark & Kiyotaki Nobuhiro, 2010, "Financial Intermediation and Credit Policy in Business Cycle Analysis", *Handbook of Monetary Economics*, in: Benjamin M. Friedman & Michael Woodford (ed.), 3(11), pp. 547-599.

Giakas Konstantinos, 2023, "Hysteresis, Financial Frictions and Monetary Policy", *The Journal of Economic Asymmetries*, 27, pp. e00286.

Giannone Domenico & Lenza Michele & Pill Huw & Reichlin Lucrezia, 2011, "Non-standard monetary policy measures and monetary developments", *ECB Working Paper No. 1290*.

Haitsma Reinder & Unalmis Deren & de Haan Jakob, 2016, "The impact of the ECB's conventional and unconventional monetary policies on stock markets", *Journal of Macroeconomics*, 48(C), pp. 101-116.

Harrison Richard, 2012, "Asset purchase policy at the effective lower bound for interest rates", *Bank of England Working Paper No. 444*.

Holmstrom Bengt & Tirole Jean, 1997, "Financial Intermediation, Loanable Funds, and The Real Sector", *The Quarterly Journal of Economics*, 112(3), pp. 663-691.

Iacoviello Matteo, 2005, "House Prices, Borrowing Constraints, and Monetary Policy in the Business Cycle", *American Economic Review*, 95(3), pp. 739-764.

Iacoviello Matteo, 2015, "Financial Business Cycles", *Review of Economic Dynamics*, 18(1), pp. 140-164.

Jensen Jakob Roager & Mikkelsen Jakob Guldbk & Spange Morten, 2017, "The ECB's unconventional monetary policy and the role of exchange rate regimes in cross-country spillovers", *DANMARKS NATIONALBANK Working Paper No. 119*.

Jermann Urban & Quadrini Vincenzo, 2012, "Macroeconomic Effects of Financial Shocks", *American Economic Review*, 102(1), pp. 238-271.

Jordá Óscar & Schularick Moritz & Taylor Alan, 2011, "When Credit Bites Back: Leverage, Business Cycles, and Crises", *NBER Working Paper No. 17621*.

Kiyotaki Nobuhiro & Moore John, 1997, "Credit Cycles", *Journal of Political Economy*, 105(2), pp. 211-248.

Kiyotaki Nobuhiro & Moore John, 2012, "Liquidity, Business Cycles and Monetary Policy", *Edinburgh School of Economics Discussion Paper No. 113*.

Laureys Lien & Meeks Roland & Wanengkirtyo Boromeus, 2021, "Optimal simple objectives for monetary policy when banks matter", *European Economic Review*, 135(C).

Lenza Michele & Pill Huw & Reichlin Lucrezia, 2010, "Monetary policy in exceptional times", *Economic Policy*, 25(62), pp. 295-339.

Meh Césaire & Moran Kevin, 2010, "The role of bank capital in the propagation of shocks", *Journal of Economic Dynamics and Control*, 34(3), pp. 555-576.

Mendoza Enrique, 2010, "Sudden Stops, Financial Crises, and Leverage", *American Economic Review*, 100(5), pp. 1941-1966.

Micossi Stefano, 2015, “The monetary policy of the European central bank (2002-2015)”, *Centre for European Policy Studies*, Special Report, 109.

Mouabbi Sarah & Sahuc Jean-Guillaume, 2019, “Evaluating the macroeconomic effects of the ECB’s unconventional monetary policies”, *Journal of Money, Credit and Banking*, 54(4), pp. 831-858.

Pattipeilohy Christiaan & Van den End Willem & Frost Jon & de Haan Jakob & Tabbae Mostafa, 2013, “Unconventional Monetary Policy of the ECB during the Financial Crisis: An Assessment and New Evidence”, *SUERF 50th Anniversary Volume Chapters*, in: Balling Morten & Gnan Ernest (ed.), 4, pp. 117-156.

Reinhart Carmen & Rogoff Kenneth, 2014, “Recovery from Financial Crises: Evidence from 100 Episodes”, *American Economic Review*, 104(5), pp. 50-55.

Sims Eric & Wu Jing Cynthia, 2020, “Wall Street vs. Main Street QE”, *NBER Working Paper No. 27295*.

Sims Eric & Wu Jing Cynthia, 2021, “Evaluating Central Banks’ tool kit: Past, present, and future”, *Journal of Monetary Economics*, 118(C) , pp. 135160.

Smets Frank & Wouters Rafael, 2007, “Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach”, *American Economic Review*, 97(3), pp. 586-606.

Urbschat Florian & Watzka Sebastian, 2020, “Quantitative Easing in the Euro Area - An Event Study Approach”, *The Quarterly Review of Economics and Finance*, 77(C), pp. 14-36.

Vayanos Dimitri & Vila JeanLuc, 2021, “A PreferredHabitat Model of the Term Structure of Interest Rates”, *Econometrica*, 89(1), pp. 77-112.

Yun Tack, 1996, “Nominal price rigidity, money supply endogeneity, and business cycles”, *Journal of Monetary Economics*, 37(2-3), pp. 345-370.

Department of Economics
Athens University of Economics and Business

List of Recent Working Papers

<u>**2021**</u>

01-21 **Historical Cycles of the Economy of Modern Greece From 1821 to the Present, George Alogoskoufis**
02-21 **Greece Before and After the Euro: Macroeconomics, Politics and the Quest for Reforms, George Alogoskoufis**
03-21 **Commodity money and the price level, George C. Bitros. Published in: *Quarterly Journal of Austrian Economics*, 2022**
04-21 **Destabilizing asymmetries in central banking: With some enlightenment from money in classical Athens, George C. Bitros. Published in: *Journal of Economic Asymmetries*, 2021**
05-21 **Exploring the Long-Term Impact of Maximum Markup Deregulation, Athanasios Dimas and Christos Genakos**
06-21 **A regularization approach for estimation and variable selection in high dimensional regression models, Y. Dendramis, L. Giraitis, G. Kapetanios**
07-21 **Tax Competition in the Presence of Environmental Spillovers, Fabio Antoniou, Panos Hatzipanayotou, Michael S. Michael, Nikos Tsakiris**
08-21 **Firm Dynamics by Age and Size Classes and the Choice of Size Measure, Stelios Giannoulakis and Plutarchos Sakellaris**
09-21 **Measuring the Systemic Importance of Banks, Georgios Moratis, Plutarchos Sakellaris**
10-21 **Firms' Financing Dynamics Around Lumpy Capacity Adjustments, Christoph Görtz, Plutarchos Sakellaris, John D. Tsoukalas**
11-21 **On the provision of excludable public goods General taxes or user prices? George Economides and Apostolis Philippopoulos**
12-21 **Asymmetries of Financial Openness in an Optimal Growth Model, George Alogoskoufis**
13-21 **Evaluating the impact of labour market reforms in Greece during 2010-2018 , Georgios Gatopoulos, Alexandros Louka, Ioannis Polycarpou, Nikolaos Vettas**
14-21 **From the Athenian silver to the bitcoin standard: Private money in a state-enforced free banking model, George C. Bitros**
15-21 **Ordering Arbitrage Portfolios and Finding Arbitrage Opportunities. Stelios Arvanitis and Thierry Post**
16-21 **Inconsistency for the Gaussian QMLE in GARCH-type models with infinite variance, Stelios Arvanitis and Alexandros Louka**
17-21 **Competition and Pass-Through: Evidence from Isolated Markets, Christos Genakos and Mario Pagliero**
18-21 **Exploring Okun's Law Asymmetry: An Endogenous Threshold LSTR Approach, Dimitris Christopoulos, Peter McAdam and Elias Tzavalis**
19-21 **Limit Theory for Martingale Transforms with Heavy-Tailed Multiplicative Noise, Stelios Arvanitis and Alexandros Louka**
20-21 **Optimal taxation with positional considerations, Ourania Karakosta and Eleftherios Zacharias**

Πατησίων 76, 104 34 Αθήνα. Τηλ.: 210 8203303-5. E-mail: econ@aueb.gr / www.aueb.gr
76, Patission Street, Athens 104 34 Greece. Tel.: (+30) 210 8203303-5

21-21 The ECB's policy, the Recovery Fund and the importance of trust: The case of Greece, Vasiliki Dimakopoulou, George Economides and Apostolis Philippopoulos

2022

01-22 Is Ireland the most intangible intensive economy in Europe? A growth accounting perspective, Ilias Kostarakos, KieranMcQuinn and Petros Varthalitis
02-22 Common bank supervision and profitability convergence in the EU, Ioanna Avgeri, Yiannis Dendramis and Helen Louri
03-22 Missing Values in Panel Data Unit Root Tests, Yiannis Karavias, Elias Tzavalis and Haotian Zhang
04-22 Ordering Arbitrage Portfolios and Finding Arbitrage Opportunities, Stelios Arvanitis and Thierry Post
05-22 Concentration Inequalities for Kernel Density Estimators under Uniform Mixing, Stelios Arvanitis
06-22 Public Sector Corruption and the Valuation of Systemically Important Banks, Georgios Bertsatos, Spyros Pagratis, Plutarchos Sakellaris
07-22 Finance or Demand: What drives the Responses of Young and Small Firms to Financial Crises? Stelios Giannoulakis and Plutarchos Sakellaris
08-22 Production function estimation controlling for endogenous productivity disruptions, Plutarchos Sakellaris and Dimitris Zaverdas
09-22 A panel bounds testing procedure, Georgios Bertsatos, Plutarchos Sakellaris, Mike G. Tsionas
10-22 Social policy gone bad educationally: Unintended peer effects from transferred students, Christos Genakos and Eleni Kyrkopoulou
11-22 Inconsistency for the Gaussian QMLE in GARCH-type models with infinite variance, Stelios Arvanitis and Alexandros Louka
12-22 Time to question the wisdom of active monetary policies, George C. Bitros
13-22 Investors' Behavior in Cryptocurrency Market, Stelios Arvanitis, Nikolas Topaloglou and Georgios Tsomidis
14-22 On the asking price for selling Chelsea FC, Georgios Bertsatos and Gerassimos Sapountzoglou
15-22 Hysteresis, Financial Frictions and Monetary Policy, Konstantinos Giakas
16-22 Delay in Childbearing and the Evolution of Fertility Rates, Evangelos Dioikitopoulos and Dimitrios Varvarigos
17-22 Human capital threshold effects in economic development: A panel data approach with endogenous threshold, Dimitris Christopoulos, Dimitris Smyrnakis and Elias Tzavalis
18-22 Distributional aspects of rent seeking activities in a Real Business Cycle model, Tryfonas Christou, Apostolis Philippopoulos and Vanghelis Vassilatos

2023

01-23 Real interest rate and monetary policy in the post Bretton Woods United States, George C. Bitros and Mara Vidali
02-23 Debt targets and fiscal consolidation in a two-country HANK model: the case of Euro Area, Xiaoshan Chen, Spyridon Lazarakis and Petros Varthalitis
03-23 Central bank digital currencies: Foundational issues and prospects looking forward, George C. Bitros and Anastasios G. Malliaris
04-23 The State and the Economy of Modern Greece. Key Drivers from 1821 to the Present, George Alogoskoufis
05-23 Sparse spanning portfolios and under-diversification with second-order stochastic dominance, Stelios Arvanitis, Olivier Scaillet, Nikolas Topaloglou

06-23 **What makes for survival? Key characteristics of Greek incubated early-stage startup(per)s during the Crisis: a multivariate and machine learning approach, Ioannis Besis, Ioanna Sapfo Pepelasis and Spiros Paraskevas**

07-23 **The Twin Deficits, Monetary Instability and Debt Crises in the History of Modern Greece, George Alogoskoufis**

08-23 **Dealing with endogenous regressors using copulas; on the problem of near multicollinearity, Dimitris Christopoulos, Dimitris Smyrnakis and Elias Tzavalis**

09-23 **A machine learning approach to construct quarterly data on intangible investment for Eurozone, Angelos Alexopoulos and Petros Varthalitis**

10-23 **Asymmetries in Post-War Monetary Arrangements in Europe: From Bretton Woods to the Euro Area, George Alogoskoufis, Konstantinos Gravas and Laurent Jacque**

11-23 **Unanticipated Inflation, Unemployment Persistence and the New Keynesian Phillips Curve, George Alogoskoufis and Stelios Giannoulakis**

12-23 **Threshold Endogeneity in Threshold VARs: An Application to Monetary State Dependence, Dimitris Christopoulos, Peter McAdam and Elias Tzavalis**

Department of Economics
Athens University of Economics and Business

The Department is the oldest Department of Economics in Greece with a pioneering role in organising postgraduate studies in Economics since 1978. Its priority has always been to bring together highly qualified academics and top quality students. Faculty members specialize in a wide range of topics in economics, with teaching and research experience in world-class universities and publications in top academic journals.

The Department constantly strives to maintain its high level of research and teaching standards. It covers a wide range of economic studies in micro-and macroeconomic analysis, banking and finance, public and monetary economics, international and rural economics, labour economics, industrial organization and strategy, economics of the environment and natural resources, economic history and relevant quantitative tools of mathematics, statistics and econometrics.

Its undergraduate program attracts high quality students who, after successful completion of their studies, have excellent prospects for employment in the private and public sector, including areas such as business, banking, finance and advisory services. Also, graduates of the program have solid foundations in economics and related tools and are regularly admitted to top graduate programs internationally. Three specializations are offered:1. Economic Theory and Policy, 2. Business Economics and Finance and 3. International and European Economics. The postgraduate programs of the Department (M.Sc and Ph.D) are highly regarded and attract a large number of quality candidates every year.

For more information:

https://www.dept.aueb.gr/en/econ/

Πατησίων 76, 104 34 Αθήνα. Τηλ.: 210 8203303-5. E-mail: econ@aueb.gr / www.aueb.gr
76, Patission Street, Athens 104 34 Greece. Tel.: (+30) 210 8203303-5