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**THE EXTERNAL  
FINANCE PREMIUM  
IN THE EURO AREA**

**A USEFUL  
INDICATOR FOR  
MONETARY  
POLICY?**

by Paolo Gelain



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## A USEFUL INDICATOR FOR MONETARY POLICY? <sup>1</sup>

by Paolo Gelain<sup>2</sup>



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<sup>1</sup> URL: [st-andrews.ac.uk/economics/staff/pages.p.gelain](http://st-andrews.ac.uk/economics/staff/pages.p.gelain) (Paolo Gelain) I developed this paper during my internship at the Capital Markets and Financial Structure Division of the European Central Bank (May–July 2009), to which I am very grateful for its hospitality. I would like to thank also Ferre De Graeve, Stefanie Flotho, Marco Jacopo Lombardi, Juan Pablo Nicolini, Diego Rodriguez-Palenzuela, Balázs Világi, and one anonymous referee because their comments and suggestions greatly helped me to improve the quality of this paper. All the remaining errors are mine.

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## Abstract

In this paper I estimate a New Keynesian Dynamic Stochastic General Equilibrium model for the Euro Area, which closely follows the structure of the model developed by Smets and Wouters (2003, 2005, 2007), with the addition of the so-called financial accelerator mechanism developed in Bernanke, Gertler and Gilchrist (1999). The main aim is to obtain a time series for the unobserved external finance premium that entrepreneurs pay on their loans, with the further aim of providing a dynamic analysis of it. Results confirm in general what was recently found for the US by De Graeve (2008), namely that (1) the model incorporating financial frictions can generate a series for the premium, without using any financial macroeconomic aggregates, that is highly correlated with available proxies for it, (2) the estimated premium is not necessarily counter-cyclical (this depends on the shock considered). Nevertheless, although in addition the model with financial frictions better describes Euro Area data than the model without them, the former is not satisfactory in many other respects. For instance, the accelerator effect turns out to be statistically not significant. However, this does not impede financial frictions from remaining a key ingredient to model. In fact, I found that the estimated premium is a very powerful predictor of inflation. It overcomes, in terms of the Mean Squared Forecast Error, the traditional output gap measure in a Phillips curve specification.

### *Key words:*

NK DSGE, Euro Area External Finance Premium, Financial Accelerator, Bayesian Estimation, Inflation Forecast

### *JEL classification:*

E4, E5, E37

## NON-TECHNICAL SUMMARY

Understanding the functioning of financial markets is extremely important given the relevant role they play in the modern economies. The recent financial crisis has stressed the necessity to have a clear idea of the mechanisms governing the financial side of the economy, especially those related to the credit markets.

This paper tries to shed some light on part of those aspects. In particular, the external finance premium, i.e. the premium entrepreneurs have to pay when they ask for credit to the banking system, given the riskiness of the project they undertake, is a key variable in the financial markets.

Unfortunately, this variable is unobservable, and only proxies are available for it. The main contribution of the paper is to produce an estimated series for the Euro Area premium, with the aim of studying its dynamic properties. This has been done already for the US, hence it is worth making a comparison. To achieve my aim I estimate a New Keynesian Dynamic Stochastic General Equilibrium (NK DSGE) model for the Euro Area featuring financial frictions with data from the first quarter of 1980 to the third quarter of 2008. The model incorporates several other sources of frictions and many structural shocks.

A complementary aim is to evaluate the ability of the external finance premium to be a good indicator for monetary policy. In other words the analysis tries to clarify the usefulness of the model with financial frictions (SWFA) for monetary policy purposes. Hence, judging whether the estimated premium has valuable properties is one of the tests used to verify whether financial frictions are a key element to model.

The analysis will highlight that this is the case, because the estimated premium displays a very high correlation (up to 85% with the AAA graded corporate bonds spreads) with some ready-to-use proxies for it.

Nevertheless, other tests on SWFA show that it has some weak points, making it potentially less interesting for the policy maker. In fact, SWFA generates time series for the macroeconomic aggregates whose second moments are very similar to those of the model without financial frictions, making the comparison between them and the observed time series hard, if not impossible. Second, the accelerator effect that SWFA theoretically

implies is not supported by the empirical evidence. The responses of the endogenous variables to shocks are not statistically distinguishable. Third, uncertainty about the amplitude of those responses increases in some cases, for instance after a monetary policy shock.

Despite all those drawbacks, the power of the external finance premium in predicting inflation re-qualifies financial frictions as an important element of a model. The premium overcomes, in terms of the Mean Squared Forecast Error, the traditional output gap measure in a Phillips curve specification, and the control models for forecast inflation consisting of a random walk and an autoregressive representation.

## 1. Introduction

The main goal of the paper is to provide a time series for a relevant economic variable which is unobserved. This is the external finance premium (EFP), i.e. the premium that risky entrepreneurs (because of the uncertainty of the projects they undertake) have to pay when they borrow funds from the banks, because there is a problem of asymmetric information and costly state verification between the two types of agents. In other words agents operate in a world of credit frictions. The analysis concerns the Euro Area and covers the period from 1980 to 2008.

The motivation behind the paper is without doubts related to the recent financial crisis. It is very important during this time of heavy disruption of the financial markets to know about the dynamic properties of the variables pertaining to those markets, among which the external finance premium is one of the most relevant. In addition to that financial markets also play a relevant role during “normal” times, so I think it is worth while to have better understanding of their functioning.

In other words, the analysis is devoted to evaluating on the one hand whether or not the model with financial frictions (SWFA) I estimate is able to capture salient features of the financial markets, like the end-of-sample financial crisis (i.e. the big increase in the corporate bond spreads). On the other hand, whether or not SWFA, and in particular the estimated EFP, can be useful for the implementation of the monetary policy in the Euro Area, for instance to predict inflation.

In order to achieve my aim, I base my analysis on a New Keynesian Dynamic Stochastic General Equilibrium model (NK DSGE) which closely follows the structure of the model developed by Smets and Wouters (2003, 2005, 2007), with the addition of the so-called financial accelerator mechanism developed in Bernanke and Gertler (1989), and already included in a basic DSGE model (Bernanke, Gertler, and Gilchrist (1999), BGG henceforth). The main advantage in using such a model is that, contrary to the last quoted theoretical contribution, several sources of nominal and real rigidities (which help in many ways in an estimated model<sup>3</sup>) and a large set of structural shocks are considered.

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<sup>3</sup>See Christiano, Eichenbaum, and Evans (2005), CEE henceforth, and Smets and Wouters (2003, 2005, 2007) for detailed discus-

To summarize the main results, I will show that although SWFA replicates the end-of-sample jump in the corporate bonds, and it better describes the Euro Area data than the model without financial frictions (SW), it is not satisfactory from many other more important points of view. In particular, the accelerator effect has been found to be not statistically significant and uncertainty about the shocks' impact on endogenous variables increases in some cases.<sup>4</sup>

Nevertheless, this does not impede financial frictions from remaining a key ingredient to model. In fact, I found that the EFP is a very powerful predictor of inflation. It overcomes, in terms of the Mean Squared Forecast Error, the traditional output gap measure in a Phillips curve specification, and the control models for forecast inflation consisting of a random walk and an autoregressive representation.

The rest of the analysis focuses on the evaluation of other important aspects of the model. In particular, I find that the estimated premium is not necessarily counter-cyclical as theoretically prescribed by BGG and empirically found for the Euro Area by previous contributions, i.e. Queijo (2005, 2008). That feature depends crucially on both the nature of the shock considered and on the assumption regarding investments adjustment costs. This characteristic is at the basis of the explanation of the evidence that the estimated premium in the Euro Area does not display any relevant regularity either during a period of recession or immediately before it (it has been found to be always increasing before a recession and always pro-cyclical during it - with the exception of the two early eighties' recessions - in De Graeve (2008) for the US<sup>5</sup>). The variance decomposition suggests that many shocks are relevant to the explanation of the variability of the premium. Given that those shocks have different implications in terms of pro/countercyclicality of the EFP, and that at any point in time they are acting contemporaneously, it is not surprising that the premium behaves accordingly, being pro/countercyclical on the basis of those shocks which dominate the others in a particular period.

With respect the confirmation of the empirical relevance of the financial frictions in

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sions about their importance in an estimated model.

<sup>4</sup>The uncertainty is measured by the amplitude of the error bands around the mean impulse response functions.

<sup>5</sup>See footnote 29 for a more detailed explanation of these findings.

the Euro Area, Queijo (2005, 2008) also deals with that topic in a similar context to mine. Her estimation ends at the fourth quarter of 2002. My paper is different in that she does not discuss analysis of the fitted EFP series described in the text. Her focus is on comparison of the relevance of the financial frictions in the US and the Euro Area. In addition, she assumes capital adjustment costs rather than investments adjustment costs, and as already stated above this assumption is at the basis of the different results in terms of pro/countercyclicality of the premium which I obtain.

There are two other papers which are worth mentioning because they contain relevant details that support or contrast with some of my results. Levin et al. (2004) use non-linear least squares to estimate the structural parameters of a canonical debt contract model with informational frictions. Using microdata for 900 US firms over the period 1997Q1 to 2003Q3, they reject the null hypothesis of frictionless financial markets.

Meier and Müller (2006) is the only published paper that reports different empirical evidence for the US. In fact, using the same financial accelerator framework (but a different estimation method) they obtain sizeable points estimates for the relevant parameters governing the financial sector, but these are not statistically significant. The same conclusion is suggested in their analysis by their distance metric tests, which show financial frictions to have only a marginal impact on improving the model's fit with the data.<sup>6</sup>

The paper is structured as follows. In the following section I present the model. In Section 3 I discuss the data I used for the estimation, and the estimation methodology adopted. In the subsequent section, I present the estimation results. In the fifth section I provide the dynamic analysis of the EFP and of the SWFA properties. Before the concluding remarks, the forecast computations are considered in Section 6.

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<sup>6</sup>I think that the explanation for those results is that they use, differently from all the quoted papers and from mine as well, a series for the corporate profits in the estimation as a proxy for the financial tightening. We are currently working on the same issue and it seems from preliminary results that using a series for the premium in the estimation strongly affects the ability of the model with financial frictions to improve the fit with the data. See Gelain et al. (2009) for details.

## 2. The model

The model is based on two previous contributions. The main structure is taken from Smets and Wouters (2003, 2005, 2007). That model is then extended, introducing the financial accelerator mechanism as in BGG. These reference papers are well known, hence I will present the model mainly in its log-linear form.<sup>7</sup>

### 2.1. Households

Household  $i$  maximizes its intertemporal utility function choosing how to consume ( $\widehat{c}_t^i$ ), the hours it wants to work ( $\widehat{l}_t^i$ ), and the amount it wants to deposit in the banks ( $\widehat{d}_t^i$ ), subject to its budget constraint. Deposits pay a one period nominal interest rate  $\widehat{r}_t^n = (1 + \widehat{i}_t^n)$ . Hence, aggregate consumption evolves according to the following Euler equation

$$\widehat{c}_t = \frac{h^{gy}}{1 + h^{gy}} \widehat{c}_{t-1} + \frac{1}{1 + h^{gy}} E_t \{ \widehat{c}_{t+1} \} - \frac{1 - h^{gy}}{\sigma_c (1 + h^{gy})} \widehat{r}_t + \frac{1 - h^{gy}}{\sigma_c (1 + h^{gy})} \widehat{\varepsilon}_t^\beta + E_t \{ \widehat{\varepsilon}_{t+1}^{gy} \} - h^{gy} \widehat{\varepsilon}_t^{gy}$$

where  $\widehat{\varepsilon}_t^\beta = \rho_\beta \widehat{\varepsilon}_{t-1}^\beta + u_t^\beta$  with  $u_t^\beta \sim N(0, \sigma_\beta^2)$  is the discount factor shock (or preference shock),  $\widehat{\varepsilon}_t^{gy} = \rho_{gy} \widehat{\varepsilon}_{t-1}^{gy} + u_t^{gy}$  with  $u_t^{gy} \sim N(0, \sigma_{gy}^2)$ . The real interest rate is simply defined as  $\widehat{r}_t = \widehat{r}_t^n - E_t \{ \pi_{t+1}^c \}$ , where  $\pi_t^c$  is the gross inflation rate  $1 + \frac{P_t^c - P_{t-1}^c}{P_{t-1}^c}$  or equivalently  $\frac{P_t^c}{P_{t-1}^c}$ , with  $P_t^c$  the CPI. The household behaviour is characterized by external habit formation, whose degree is established by parameter  $h$  (with  $h^{gy} = h/g_y$  and  $g_y$  is the average growth rate<sup>8</sup>). Households have a positive utility in period  $t$  only if they are able to consume something more than what was consumed during the previous period on average. The inverse of the intertemporal elasticity of substitution in consumption (or equivalently the coefficient of relative risk aversion) is  $\sigma_c$ .

<sup>7</sup>Hatted variables refer to the percentage deviation from their steady state value. For instance  $\widehat{c}_t = \frac{C_t - C}{C}$ , where  $C_t$  is the level of consumption at time  $t$  and  $C$  is its steady state level.

<sup>8</sup>See Section 2.2.3 for further details.

### 2.1.1. Labour Supply

Each household is a monopolistic supplier of a differentiated labour service requested by the domestic firms<sup>9</sup>. This implies that the households can determine their own wage. After having set their wages, households inelastically supply the firms' demand for labour at the going wage rate.

There is a firm which hires labour from the households and transforms it into a homogenous input good  $\widehat{l}_t$ . It is assumed that not all households can optimally set their wage each period. On the basis of the Calvo assumption (see Calvo (1983)), only a fraction  $1 - \xi_w$  of households can re-optimize. For those who cannot, wages evolve according to  $W_{t+1}(i) = (\pi_t^c)^{\tau_w} W_t(i)$ . Given this set-up, households optimize their wages conditionally upon the fact that there is a certain probability that they cannot re-optimize in the future. The resulting wage equation is as follows

$$\begin{aligned} \widehat{w}_t = & \frac{\beta}{1+\beta} E_t \{ \widehat{w}_{t+1} \} + \frac{1}{1+\beta} \widehat{w}_{t-1} + \frac{\beta}{1+\beta} E_t \{ \widehat{\pi}_{t+1}^c \} - \frac{1+\beta\tau_w}{1+\beta} \widehat{\pi}_t^c + \frac{\tau_w}{1+\beta} \widehat{\pi}_{t-1}^c + \\ & - \frac{1}{1+\beta} \frac{(1-\beta\xi_w)(1-\xi_w)}{\left[1 + \frac{(1+\lambda_w)\sigma_L}{\lambda_w}\right] \xi_w} \left\{ \widehat{w}_t - \sigma_L \widehat{l}_t - \frac{\sigma_c}{1-h^{gy}} [\widehat{c}_t - h^{gy} (\widehat{c}_{t-1} + \widehat{\varepsilon}_t^{gy})] \right\} + \widehat{\varepsilon}_t^w \end{aligned}$$

where  $\widehat{\varepsilon}_t^w = \rho_w \widehat{\varepsilon}_{t-1}^w + u_t^w$  with  $u_t^w \sim N(0, \sigma_w^2)$  is the wage mark-up shock and  $\lambda_w$  is the steady state value of the latter. The inverse of the elasticity of work effort with respect to the real wage is  $\sigma_L$ .

### 2.2. Firms

There are three types of producers: entrepreneurs, capital producers and retailers. Entrepreneurs produce intermediate goods. They borrow from a financial intermediary that converts household deposits into business financing for the purchasing of capital. The presence of asymmetric information between entrepreneurs and lenders creates a financial friction that makes the entrepreneurial demand for capital dependent on their financial position. Capital producers buy final goods to produce capital to be sold to the entrepreneurs.

<sup>9</sup>The main references are Kollmann (1997), Erceg et al. (2000), CEE (2005). Most recent references are Adolfson et al. (2007a,b) and Fernandez-Villaverde and Rubio Ramirez (2007). The latter has very good mathematical derivations.



Retailers are described in the following section.

### 2.2.1. Retailers

Firms in this sector operate in a perfectly competitive market. That is, products of individual firms,  $y_t(j)$ , are not perfect substitutes and they are aggregated by the following Dixit-Stiglitz technology

$$Y_t = \left( \int_0^1 y_t(j)^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}},$$

where  $\theta > 1$  measures the elasticity of substitution. This implies that the demand for the product of an individual firms is determined by

$$y_t(j) = \left( \frac{P_t^c}{P_t(j)} \right)^{-\theta} Y_t, \quad (1)$$

where  $P_t^c$  is the aggregate price index,  $P_t(j)$  is the price of firm  $j$ .

### 2.2.2. Capital Producers

Capital producers are competitive and take prices as given. They buy final consumption goods at price  $P_t^c$ , transforming them into investment goods to be sold to the entrepreneurs at price  $P_t^I$ . They face investment adjustment costs, hence with  $I_t$  units of consumption goods purchased they produce  $\left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t x_t$  units of investment goods, where  $\widehat{x}_t = \rho_x \widehat{x}_{t-1} + u_t^x$  with  $u_t^x \sim N(0, \sigma_x^2)$  is a shock to the marginal efficiency of investments, and  $S\left(\frac{I_t}{I_{t-1}}\right)$  is the investment adjustment costs function. It has the same properties assumed in many previous papers (see for instance CEE 2005), namely  $S(1) = S'(1) = 0$  and  $S''(1) > 0$ .

The dynamics of investments is then described by the following equation

$$\widehat{i}_t = \frac{1}{1+\beta} \widehat{i}_{t-1} + \frac{\beta}{1+\beta} E_t \{\widehat{i}_{t+1}\} + \frac{1}{\varphi(1+\beta)g_y^2} \widehat{q}_t + \frac{1}{g_y^2} \widehat{x}_t - \widehat{\varepsilon}_t^{gy} \quad (2)$$

where  $\varphi$  is the inverse of investment adjustment cost and  $\widehat{q}_t = (Q_t - 1) \equiv \frac{P_t^I}{P_t^c} - 1$ .

The stock of capital evolves as follows

$$\widehat{k}_t = \frac{\delta}{g_y} (\widehat{i}_t + g_y^2 \varphi \widehat{x}_t) + \frac{(1-\delta)}{g_y} (\widehat{k}_{t-1} - \widehat{\varepsilon}_t^{gy})$$

where  $\delta$  is the depreciation rate of capital.

### 2.2.3. Entrepreneurs

The activity of entrepreneurs is at the heart of the model, therefore I will focus on their behaviour in greater detail than I do for the other two types of firm. They are involved in two kinds of activities: the production of wholesale goods and the stipulation of financial contracts to obtain funds to finance the former activity. I will describe these two activities, starting with the former.

Entrepreneurs operate in a monopolistically competitive market. They hire labour  $\widehat{l}_t$  from households, paying the salary  $\widehat{w}_t$ , and capital at price  $\widehat{q}_t$  with a marginal productivity equal to  $\widehat{r}e_t^k$ . Entrepreneurs produce output  $\widehat{y}_t$  on the basis of the following Cobb-Douglas production function<sup>10</sup>

$$\widehat{y}_t = (1 + \phi) \left[ \widehat{a}_t + \alpha (\widehat{k}_{t-1} - \widehat{\varepsilon}_t^{gy}) + \alpha \psi \widehat{r}e_t^k + (1 - \alpha) \widehat{l}_t \right]$$

where  $\psi = \frac{\Psi'(1)}{\Psi''(1)}$  is the inverse of the elasticity of the capital utilization cost function,  $\widehat{a}_t = \rho_a \widehat{a}_{t-1} + u_t^a$ , with  $u_t^a \sim N(0, \sigma_a^2)$ , is the technology shock, and  $\phi$  is the share of fixed cost in production.<sup>11</sup>

Using the f.o.c.s from the minimization cost problem an expression can be derived for the real marginal cost

$$\widehat{mc}_t = \alpha \widehat{r}e_t^k + (1 - \alpha) \widehat{w}_t - \widehat{a}_t$$

<sup>10</sup>This formulation of the Cobb–Douglas production function is due to the fact that I assumed the presence of unit root labour augmenting productivity growth  $M_t$  such that

$$Y_t = \exp(A_t) (z_t K_{t-1})^\alpha (M_t L_t)^{(1-\alpha)} - M_t F$$

where  $\frac{M_t}{M_{t-1}} = g_y \exp(\varepsilon_t^{gy})$ . The model is then stationarized by normalizing all the real variables by  $M_t$ .

<sup>11</sup>Adjustment cost of capital utilization is represented by the following function,

$$\Psi(z_t) = Re^k \psi \left[ \exp\left(\frac{z_t - 1}{\psi}\right) - 1 \right],$$

where  $\Psi(1) = 0$ ,  $\Psi'(1) = Re^k$  and  $\Psi'(1)/\Psi''(1) = \psi$ . The degree of capital utilization is determined by condition  $\Psi'(z_t) = Re_t^k$ . This implies that

$$\begin{aligned} z_t &= \psi \ln\left(\frac{Re_t^k}{Re^k}\right) + 1, \\ \Psi(z_t) &= \psi (Re_t^k - Re^k). \end{aligned}$$

The above two expressions are used to replace variable  $z_t$  by  $Re_t^k$ .

Together with the following condition on the return on capital

$$(1 + \psi) \widehat{r}e_t^k = \widehat{l}_t + \widehat{w}_t - \widehat{k}_{t-1} + \widehat{\varepsilon}_t^{gy}$$

it is possible to determine the marginal productivity of all the input factors, and their demand schedule as a consequence.

Entrepreneurs also decide the level of capital utilization according to the following first order condition<sup>12</sup>

$$\widehat{r}e_t^k = \psi z_t$$

Turning to the problem of setting the loan contract with the financial intermediaries, the entrepreneurs' behaviour follows that proposed by BGG. Entrepreneurs are risk neutral and have a finite expected horizon for planning purposes. The probability that an entrepreneur will survive until the next period is  $\vartheta^e$ , so the expected lifetime horizon is  $1/(1 - \vartheta^e)$ . This assumption ensures that entrepreneurs' net worth  $\widehat{nw}_{t+1}$  (the firm equity) will never be enough to fully finance the new capital acquisition.

In essence, they issue debt contracts to finance their desired investment expenditures in excess of net worth. The capital acquisition is financed then partly by their net worth and partly by borrowing from a financial intermediary. This intermediary obtains its funds from household deposits and faces an opportunity cost of funds equal to the economy's riskless rate of return,  $\widehat{r}_t^n$ . Thus, in order to acquire a loan, entrepreneurs have to engage in a financial contract before the realization of an idiosyncratic shock  $\omega^j$  (with a payoff paid after the realization of the same shock).<sup>13</sup>

The ex-post return on capital for firm  $j$  is  $\omega^j \widehat{r}_{t+1}^k$ ,<sup>14</sup> where  $\widehat{r}_{t+1}^k$  is the ex-post aggregate return to capital (i.e. the gross return averaged across firms). The latter is related to the

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<sup>12</sup>The problem they solve is

$$\max_{\{z_t\}} R e_t^k z_t K_{t-1} - \Psi(z_t) K_{t-1}$$

where  $\Psi(z_t)$  is the cost of capital utilization function.

<sup>13</sup>The idiosyncratic shock has positive support, is independently distributed (across entrepreneurs and time) with a cumulative distribution function  $F(\omega^j)$  with unitary mean ( $E\{\omega^j\} = 1$ ), and density function  $f(\omega^j)$ . As in BGG I assume a log normal distribution which has a positive support.

<sup>14</sup>The return of the entrepreneurial investment is observable to the outsider only through the payment of a monitoring cost  $\mu \omega^j R_{t+1}^k Q_t K_{t+1}^j$ , where  $\mu$  is the fraction of the lender's output lost in monitoring costs.

price of capital as follows

$$\widehat{r}_{t+1}^k = \frac{R e^k}{R^k} \widehat{r}_{t+1}^k + \frac{(1 - \delta)}{R^k} \widehat{q}_{t+1} - \widehat{q}_t \quad (3)$$

Equation 3 is nothing more than the term structure of interest rate if taken in expectations and solved forward.

Turning to the loan contract, the entrepreneur chooses the value of firm capital and the associated level of borrowing prior to the realization of the idiosyncratic shock. Given that, the optimal contract is characterized by a gross non-default loan rate and by a threshold value of the idiosyncratic shock  $\omega^j$ , call it  $\bar{\omega}^j$ , such that for values greater than or equal to  $\bar{\omega}^j$ , the entrepreneur is able to repay the loan at the contractual rate. A defaulting entrepreneur receives nothing.

The values of  $\bar{\omega}^j$  and of the gross non-default loan rate under the optimal contract are determined by the requirement that the financial intermediary should receive an expected return equal to the opportunity cost of its funds  $\widehat{r}_{t+1}^n$ .

From the first order conditions of the optimal contract a key aggregate relationship for the financial accelerator mechanism is obtained

$$\widehat{s}_t = -\varkappa \left( \widehat{nw}_{t+1} - \widehat{q}_t - \widehat{k}_{t+1} + \widehat{\varepsilon}_t^{sy} \right)$$

where  $\widehat{s}_t \equiv E_t \widehat{r}_{t+1}^k - \widehat{r}_t$  is the external finance premium and  $\varkappa$  is the elasticity of the external finance premium with respect to the leverage ratio, the key parameter to be estimated. This summarizes the idea underlying the financial accelerator. This idea is that the EFP is negatively related to the net worth of the potential borrower. The intuition is that firms with higher leverage (lower net worth to capital ratio) will have a greater probability of defaulting and will therefore have to pay a higher premium. Since net worth is pro-cyclical (because of the pro-cyclicity of profits and asset prices), the external finance premium becomes counter-cyclical and amplifies business cycles through an accelerator effect on investment, production and spending.

The aggregate entrepreneurial net worth at the end of period t is given by

$$\widehat{nw}_{t+1} = \vartheta^e \left[ \frac{K}{NW} R^n (S \widehat{r}_t^k - \widehat{r}_t) + \frac{K}{NW} R^n (S - 1) (\widehat{q}_{t-1} + \widehat{k}_t - \widehat{\varepsilon}_t^{sy}) + R^n \left( \widehat{r}_t + \frac{1}{g_y} \widehat{nw}_t \right) \right] \quad (4)$$

Equation 4, which is the second basic ingredient of the financial accelerator, states that the entrepreneurial net worth is equal to the return on capital minus its cost minus the cost of an eventual default.

Intermediate goods producers face another type of problem. Each period, only a fraction  $1 - \xi_\pi$  of them, randomly chosen, can optimally adjust their prices. For those who cannot re-optimize, prices are adjusted according to  $P_{t+1}^c = (\pi_t^c)^{\tau_\pi} P_t^c$ , where  $\tau_\pi$  is the parameter which governs the degree of price indexation to past inflation.

Maximizing the expected discounted profits subject to the constraint represented by the demand expressed by the final good producers for the intermediate goods (equation 1), it is possible to derive the condition for the optimal price and consequently the NKPC<sup>15</sup>

$$\widehat{\pi}_t^c = \frac{\beta}{1 + \beta\tau_\pi} E_t \{ \widehat{\pi}_{t+1}^c \} + \frac{\tau_\pi}{1 + \beta\tau_\pi} \widehat{\pi}_{t-1}^c + \frac{1}{1 + \beta\tau_\pi} \frac{(1 - \beta\xi_\pi)(1 - \xi_\pi)}{\xi_\pi} (\widehat{mc}_t) + \widehat{\varepsilon}_t^{\lambda^\pi}$$

where  $\widehat{\varepsilon}_t^{\lambda^\pi} = \rho_{\lambda^\pi} \widehat{\varepsilon}_{t-1}^{\lambda^\pi} + u_t^{\lambda^\pi}$  with  $u_t^{\lambda^\pi} \sim N(0, \sigma_{\lambda^\pi}^2)$  is the price mark-up shock.

### 2.3. Monetary policy

As a benchmark rule,<sup>16</sup> the empirical interest-rate rule of the SW model is added:

$$\widehat{r}_t^i = \phi_m \widehat{r}_{t-1}^i + (1 - \phi_m) [r_\pi (\widehat{\pi}_{t-1}) + r_y (\widehat{y}_{t-1} - \widehat{y}_{t-1}^*)] + r_{\Delta\pi} (\widehat{\pi}_t - \widehat{\pi}_{t-1}) + r_{\Delta y} [\widehat{y}_t - \widehat{y}_t^* - (\widehat{y}_{t-1} - \widehat{y}_{t-1}^*)] + u_t^{ru}$$

where  $\widehat{y}_t^*$  is the flexible-price level of output and  $u_t^{ru} \sim N(0, \sigma_{ru}^2)$  is the monetary policy shock.

### 2.4. Government

Fiscal policy is exogenous and is described by  $\widehat{g}_t = \rho_g \widehat{g}_{t-1} + u_t^g$ , where  $u_t^g \sim N(0, \sigma_g^2)$ . In addition there is the equilibrium condition that  $G_t = T_t$ .

<sup>15</sup>In order to maintain the paper self-contained I do not report here the derivation of the New Keynesian Phillips curve. Moreover, it has been derived in many papers and books; see for instance, Adolfson et al. (2007a,b) and Fernandez-Villaverde and Rubio Ramirez (2007) among others.

<sup>16</sup>I have chosen this rule to make the model as comparable as possible with the previous contributions. In particular it is the same rule used in Smets and Wouters.

## 2.5. Aggregation

The resource constraint

$$\widehat{y}_t = \frac{C}{Y}\widehat{c}_t + \frac{I}{Y}\widehat{i}_t + \frac{G}{Y}\widehat{g}_t + \frac{1}{g_y} \left[ \frac{K}{Y}\psi Re^k \widehat{r}e_t^k + \frac{K}{Y}S \left(1 - \frac{NW}{K}\right) (\widehat{r}_t^k + \widehat{q}_{t-1} + \widehat{k}_t - \widehat{\varepsilon}_t^{gy}) \right]$$

The model is estimated using real variables' growth rates. Hence, I need to define them as follows

$$\begin{bmatrix} \widehat{y}_t^g \\ \widehat{c}_t^g \\ \widehat{i}_t^g \\ \widehat{w}_t^g \\ \widehat{E}_t^g \end{bmatrix} = \begin{bmatrix} \widehat{y}_t - \widehat{y}_{t-1} \\ \widehat{c}_t - \widehat{c}_{t-1} \\ \widehat{i}_t - \widehat{i}_{t-1} \\ \widehat{w}_t - \widehat{w}_{t-1} \\ \widehat{E}_t - \widehat{E}_{t-1} \end{bmatrix} + \begin{bmatrix} \widehat{\varepsilon}_t^{gy} \\ \widehat{\varepsilon}_t^{gy} \\ \widehat{\varepsilon}_t^{gy} \\ \widehat{\varepsilon}_t^{gy} \\ 0 \end{bmatrix}$$

## 3. Data and estimation methodology

Some parameters are fixed prior to estimation because the data used contain little information about them. The remaining parameters not mentioned in the text are computed according to the steady state relationships reported in AppendixA. The discount factor  $\beta$  is set equal to 0.99, implying an annual steady state real interest rate of 4% (or equivalently a quarterly rate of 1%). The parameter  $\theta$  is set equal to 6, implying a steady-state price markup of 20%, a common value used in the literature. The depreciation rate,  $\delta$ , is assigned the commonly used values of 0.025. The parameter of the Cobb-Douglas function,  $\alpha$ , is set equal to 0.3. As in BGG, in order to have an annualized business failure rate,  $F(\bar{\omega})$ , of 3% (0.75% quarterly), a steady state risk spread,  $R^k - R^n$ , equal to 200 basis points, and a ratio of capital to net worth,  $\frac{K}{NW}$ , of 2 (or equivalently a leverage ratio of 0.5), I take the idiosyncratic productivity variable,  $\log(\omega)$ , to be log-normally distributed with variance equal to 0.07, and I set the fraction of realized payoffs lost in bankruptcy,  $\mu$ , to 0.12. The steady state share of consumption is set equal to 0.60. The gross average growth rate  $g_y$  is set to 1.0039, given the quarterly output growth rate of 0.39%. Table B.1 summarizes the calibrated parameters.

[Table B.1 here]

### 3.1. Data

I used aggregate data for the Euro Area. I took them from the Area Wide Model (AWM) database.<sup>17</sup> The sample period runs from the first quarter of 1980 to the third quarter of 2008; hence I have 115 quarterly observations. I have chosen the following seven observable variables for the estimation: real GDP, real consumption, real gross investment, hours worked,<sup>18</sup> nominal short term interest rate, real wages and inflation rate. As in Smets and Wouters (2003) all real variables are in per capita terms (obtained by dividing real aggregate variables by the labour force) and in logarithmic terms. Inflation rate is the quarter by quarter variation in the GDP deflator.

The model is estimated using the growth rate of the real variables.<sup>19</sup> In order to be consistent with their theoretical definition, the common trend  $g_y$  is subtracted from all of them, with the exception of employment.<sup>20</sup> The choice of the growth rates is motivated by the fact that in a previous attempt to estimate the model using a linear trend for the real variables the estimated series for the premium I obtained failed to replicate the end-of-sample crisis (this also justifies the introduction of the unit root shock). The linear trend was excessively smoothing the last observations, while other filters (like the HP one) weighted them too much. This is also the reason why results were not robust using different detrending methods.

As for the inflation rate and interest rate, they are detrended with their own third-order exponential trend.<sup>21</sup> The use of that filter is justified by the fact that those variables clearly

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<sup>17</sup>See Fagan et al. (2001).

<sup>18</sup>As for the hours worked, there are no data available. Assuming that in any period only a fraction of firms,  $\xi_E$ , is able to adjust employment to its desired total labour input, they are obtained using the following formula (see Adolfson et al. (2007a) for further details)

$$\Delta \widehat{E}_t = \beta E_t \Delta \widehat{E}_{t+1} + \frac{(1 - \xi_E)(1 - \beta \xi_E)}{\xi_E} (\widehat{I}_t - \widehat{E}_t)$$

where  $E_t$  is the total employment at time  $t$  and  $\widehat{E}_t$  is the percentage deviation of the employment from the mean ( $\widehat{E}_t = \frac{E_t - E}{E}$ ). The parameter  $\xi_E$  is estimated.

<sup>19</sup>Recent articles estimating DSGE models using observed growth rates are Justinano and Primiceri (2008) and Coogley et al. (2009).

<sup>20</sup>The way I introduced the unit root technology shock and the way in which I deal with the consistency between the theoretical variables and their empirical counterparts follows Világi (2008).

<sup>21</sup>Differently from Smets and Wouters (2003), where there was a clear common trend between inflation and interest rate, adding the observations after 1999 makes things different, not justifying the practice of detrending the interest rate with the same trend of inflation.

display a non-linear trend. The use of the HP filter is not safe for many reasons.<sup>22</sup> In any case results are robust to the use of such a filter with a smooth parameter equal to 40000. Finally, the estimation gives similar results if raw data for inflation and interest rate are used, following the procedure described in Canova (2009).

### 3.2. Methodology

The first step taken before the estimation is solving the model for the rational expectations (see Sims (2000)). After that the aim of the estimation is to obtain the posterior distributions of the parameters and make inference out of them. Since the posterior distributions are unknown, I used a Markov Chain Monte Carlo (MCMC) simulation method, namely the so-called random walk Metropolis-Hasting algorithm, which uses an acceptance/rejection rule to converge to the posterior distribution.<sup>23</sup> Before the simulation the maximization of the posterior kernel has been done in order to find the posterior modes and the variance-covariance matrix (evaluated at the modes) to be used in the initialization of the Metropolis-Hasting algorithm.<sup>24</sup> The entire procedure is implemented in Dynare for Matlab (see Juillard (2004)). For a detailed description of it see An and Schorfheide (2007) and Canova (2007).

#### 3.2.1. Priors

Priors are taken from Smets and Wouters (2003) for the common parameters. It is common to assign a beta distribution to the coefficients defined in the range 0-1, typically the autoregressive coefficients.

In what concerns the BGG parameters, I assign a beta distribution also to the entrepreneur's rate of survival. As for the elasticity of the external finance premium with respect to firm leverage, I assume an inverse gamma distribution with mean 0.05 and infinite variance.

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<sup>22</sup>All these reasons are well described in Canova (1998, 2007). What is important to stress is his recommendation to “compile statistics using a variety of shrewdly selected detrending methods”.

<sup>23</sup>I run two chains of 500000 draws each, the acceptance rate has been tuned to be around 25% and the convergence of the chains has been evaluated with the checks proposed by Brooks and Gelman (1998). See figures C.1 and C.2.

<sup>24</sup>Dynare allows for different kinds of optimization procedure. Here, I used Sims' optimizer.

Table B.4 summarizes the distributions assigned with their mean and standard deviation.

### 3.3. Model Comparison

There are many ways to evaluate the goodness of the fit between the model with financial frictions and that without them. The main two are comparing the fitted values with the actual data and computing some test statistics. In this section I explain how a specific statistic of the Bayesian econometrics, the Bayes factor, is built and I will comment on the results in the next section. First, the models' marginal data density must be calculated. Let us label a model with financial frictions  $M_{SWFA}$ , and an alternative specification of the model without financial frictions,  $M_{SW}$ .

The Bayes factor is  $B_{SWFA, SW} = \frac{p(Y|M_{SWFA})}{p(Y|M_{SW})}$ .<sup>25</sup> Jeffreys (1961) suggested rules of thumb to interpret the Bayes factor as follows:

[Table B.2 here]

## 4. Estimation results

### 4.1. Fit

Figures C.3 and C.4 report the fitted and the actual values of the series used in the estimations.

[Figure C.3 here]

[Figure C.4 here]

The graphical analysis is quite intuitive, but it gives no clear understanding of which model better fits the data in this case. That is the reason why I need a statistics to properly

<sup>25</sup>The marginal data density for each model will be ( $i = SWFA, SW$ )

$$p(Y|M_i) = \int p(Y|\mathfrak{S}_i, M_i)p(\mathfrak{S}_i|M_i)d\mathfrak{S}_i$$

where  $\mathfrak{S}_i$  is a vector of parameters of model  $i$ ,  $p(Y|\mathfrak{S}_i, M_i)$  is the sample density of model  $i$  and  $p(\mathfrak{S}_i|M_i)$  is the prior density of the parameters for model  $i$ . See Kass and Raftery (1995) for details.

judge the fit. As anticipated I use the Bayes factor. It is reported in table B.3 and I can see that there is decisive evidence against the model without the financial accelerator effect. Thus, the introduction of the accelerator mechanism improves the model's ability to fit the data.

[Table B.3 here]

## 4.2. Posteriors

In table B.4 I report the mean values of the posterior distributions, together with their 90% probability intervals, for both the model with and that without financial frictions. The full priors and posteriors distribution can be found in AppendixC.1.

In general the posterior means are in line with previous estimations for the Euro Area and they are not very different comparing the two specifications of the model.<sup>26</sup> I will not describe them here because they are already extensively described in the previous literature, and I will focus instead on the most relevant estimated parameter  $\kappa$ .

The mean of  $\kappa$ 's posterior distribution is about 0.03. Its mode is 0.02 and the median is equal to 0.025. These values are lower than the BGG calibrated one for the US (0.05) but still in line with it (given the probability interval) and with the empirical evidence. In fact, the previous estimation for the Euro Area reports a mean value for that parameter of 0.05 in Queijo (2005) (revised to 0.04 in the 2008 version of her 2005 paper).<sup>27</sup> De Graeve (2008) reports a higher value for the US (a posterior mode of 0.1). Gilchrist et al. (2009) report a mean and a mode both equal to 0.04 for US. Christensen and Dib (2008) report a point estimate of 0.042 for Canada. Lopez and Rodriguez (2008) estimate a posterior mean of 0.059 for Colombia, and Elekdag et al. (2005) a median of 0.066 for Korea (revised to 0.048 in Elekdag et al. (2006)).

Gelain and Kulikov (in press) report a mean value of 0.13 for Estonia. This last result is due to the assumption of a higher steady state value for the premium (according to the Estonian evidence) which impacts on the value of  $\kappa$ , and hence on its prior mean, since

<sup>26</sup>The same is true in Queijo (2005, 2008), but for instance not in De Graeve (2008).

<sup>27</sup>The author does not estimate that parameter, but other structural parameters whose combination gives  $\kappa$ .

they are strongly correlated.<sup>28</sup>

[Table B.4 here]

## 5. Premium

### 5.1. A series for the premium

Figure C.5 shows the smoothed series for the risk premium obtained by the estimation of the DSGE model. I also included in the diagram the shaded areas that correspond to the recession periods.<sup>29</sup>

This figure clearly highlights that the premium does not enter recession periods in a straightforward way. Contrary to De Graeve (2008), who finds a semblance of regularity in the premium's behaviour during recessions,<sup>30</sup> but which is above all contrary to the theoretical prescription of BGG, in my case the pattern is irregular. This is the first evidence that the premium might not be only either pro- or counter-cyclical. The question is: what is the explanation behind that fact? I will answer this in the following sections, making use of the variance decomposition and of the IRF analysis. To anticipate the answer, I can state that the premium's movements depend on the nature of the shock considered and on the dominant shock driving it at any point in time.

[Figure C.5 here]

### 5.2. External validation

One of the main goals of the paper is to evaluate the strength of the model to produce a sensible and meaningful series for the unobserved risk premium. In order to evaluate

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<sup>28</sup>See BGG's appendix for details about that correlation.

<sup>29</sup>I adopted as the definition for a recession a negative GDP growth for at least two quarters in a row.

<sup>30</sup>The author shows that his model generates a premium that is always pro-cyclical. i.e. decreasing during recessions, with the exception of the two early eighties' ones. The reason is clear. His analysis highlights that the main driving shock of the premium is the investment specific shock. This explains almost 90% of its variability. In addition, with his shock decomposition he concludes that investment specific shock traces the low frequency components of the premium very closely. Given that his IRF analysis stresses that such shock generates a pro-cyclical premium, it is not surprising that during a recession it drops. As for the eighties, his model attributes both the fall in GDP and the rise in the premium to restrictive monetary policy shocks.

that feature for my model I compare the smoothed series generated by the DSGE model with some available proxies for the premium of the Euro Area. On the one hand, they are spreads computed as the difference between some risky interest rates and the risk-free interest rate represented in my case by the rate on the ten years government bonds. On the other hand I use the change in the credit standards applied by banks on loans to enterprises. The change is measured as the net percentage of banks reporting a tightening of standards compared with the previous quarter.<sup>31</sup>

Unfortunately, these series are shorter than the sample period, so I can only consider the last part of the generated series. In particular, the spreads are available only from the first quarter of 2000. These spreads are computed as the difference between the AAA, AA, A and BBB rated bonds and the ten years government bonds.<sup>32</sup> Credit standards' changes are available from the first quarter of 2003.

Figure C.6 shows the series for the spreads compared with the last part of the series of the premium in figure C.5. The comparison with the credit standards is reported in figure C.7.<sup>33</sup> The graphical analysis suggests that the model generates an extremely good series for the premium. What is reassuring is its ability to pick up the end-of-sample crisis. Confirmation of that satisfactory aspect comes from the contemporaneous correlations among the series reported in table B.5. All correlations are very high, but it seems that the EFP can be very well approximated by the AAA rated bonds spread. The correlation with the credit standards is weaker. I attribute this weakness mainly to the shortness of the series, but also to the possible biases due to the fact that data are collected since few years only.<sup>34</sup> However, a correlation of 0.44 is satisfactory.

Comparison of standard deviations, also reported in table B.5, gives a less good picture. The EFP displays a much lower standard deviation, 0.04, than the proxies, which are 0.19, 0.29, 0.27 and 0.67 for the AAA, AA, A and BBB proxy respectively, and 0.19 for the

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<sup>31</sup>Data are taken from the ECB's bank lending survey. There are two degrees of tightening: *Tightened considerably* and *Tightened somewhat*. I summed them to have an overall measure. However, results hold when the single series are used.

<sup>32</sup>Data from the ECB.

<sup>33</sup>All series are standardized to facilitate the comparison.

<sup>34</sup>The limits of the credit standards series as an indicator of strain in the availability of external finance may be seen through its not high correlation with the AAA and AA proxies, 0.48 and 0.53 respectively, and through its high correlation, but not as high as the correlations among spreads (all above 0.85) for the period 2003q1-2008q3, with the A and BBB proxies.

credit standards.<sup>35</sup>

[Figure C.6 here]

[Table B.5 here]

### 5.3. Variance decomposition

The variance decomposition presented in table B.7 shows very well which shocks are more relevant in the Euro Area and which account for the most of the variance of the single variables. Two of them are of particular interest, output and the premium, because this is the first step in understanding why the premium moves as described in section 5.1. The second step is to clarify the implications of these shocks for the premium through the IRF analysis in the next section.

[Table B.7 here]

Results presented in B.7 are in line with those of the literature related to the Euro Area. I will first describe them in general, focusing afterwards on the most interesting decomposition of the premium.

In general, in the long run, the most important shock driving the variability of the real variables is the technology shock. The wage mark-up shock is the second source of variability for real variables (with the exception of the price of capital, which is affected more by the investment specific shock).<sup>36</sup> Nominal variables are mainly driven by the monetary policy shock, although the preference shock also plays a relevant part in some cases (e.g. inflation and nominal interest rate). Government spending shock and  $u^{sy}$  are not important shocks.

Turning to the risk premium, as in De Graeve (2008), the shocks most responsible for its variability in the long run are the investment specific and the technology shocks (90% in the US case). In my case they account for 41%. The remaining part is equally

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<sup>35</sup>Credit standards' standard deviation is computed for the period 2003q1-2008q3. The EFP's standard deviation for that period is 0.04.

<sup>36</sup>In Smets and Wouters (2005) the second most important shock is that of the labour supply. Since I did not consider it, its role is taken by the wage mark-up shock.

explained by the wage mark-up shock (23%), and by the monetary policy shock (21%), which represents a difference with respect to the US where that shock is less relevant at these long horizons (around 10%). The difference is not trivial, because it is at the heart of the difference between the features of the premium in the US and in the Euro Area. In fact, as the IRFs will show, the monetary policy shock has different implications for the premium from the other three mentioned shocks. It is in the mutual interaction of different shocks with opposite effects on the premium at any point in time that I find the explanation of the premium's trajectories during the crisis.

#### **5.4. Impulse response functions**

This section focuses on the impulse response functions (IRFs) analysis. I would like to stress that the analysis in this section only aims to highlight on the one hand the cyclical behaviour of the premium after shocks hit the economy, and on the other hand that SWFA in principle replicates (partially) correctly the accelerator mechanism. It is not my intention to establish at the moment its empirical relevance. Hence, I will not include error bands in figures C.8, C.9, C.10, and C.11. This will be done in section 5.5.

Here I only report those IRFs related to the most interesting shocks, i.e. those which allow me to highlight some specific aspects of SWFA. These are, in other words, the shocks I found to be relevant in explaining the premium in the previous section, i.e. the investment specific, technology, monetary policy and wage mark-up shocks.

In figure C.8 I report the consequences of a monetary policy shock. The mechanism of the financial accelerator is clearly represented and clearly demonstrated in the response of investments. After the tightening of the monetary policy, investments decrease as in the normal set-up. This has the usual effect of reducing the demand for capital and then its price. In the financial accelerator framework, the latter reduction leads to a decrease of the net worth which makes the entrepreneur riskier. He has then to pay a higher premium and this fact further depresses investments, generating the extra response displayed in the figure.

[Figure C.8 here]

[Figure C.9 here]

[Figure C.10 here]

[Figure C.11 here]

Confirming the theoretical prescriptions (BGG and Walentin (2005)) and the empirical findings, the premium turns out to be counter-cyclical if a monetary policy shock hits the economy.<sup>37</sup>

I then analyze the investment specific shock and the technology shock, in figure C.10 and C.9 respectively, to highlight one important result that applies in the Euro Area as in the US, namely the not necessarily counter-cyclicality of the premium.

In fact, in the case of the positive investment specific shock that property is evident. The premium increases because the investment specific shock is a supply shock, given the fact that it implies a reduction in the price of capital, despite the fact that investments increase, and this leads to a decrease of the net worth which gives less collateral to entrepreneurs who in turn have to face a higher premium. The premium is then pro-cyclical.

The same is true in the case of the technology shock, although the EFP is counter-cyclical at the beginning. It becomes pro-cyclical after some time because I assumed investments adjustment costs. Under that assumption changing investments is costly for entrepreneurs.<sup>38</sup> When investments increase because of the positive productivity shock they will be positive for a protracted period of time, in order to minimize costs associated with changing their flow. This pushes the EFP to rise because entrepreneurs' borrowing needs are increasing over time due to high investments. This is the same mechanism described by De Graeve (2008) for the US.

Nevertheless, there is an important difference. In fact, the US evidence shows that long lasting positive investments will be costly due to a high future EFP, and as a consequence investments will be lower in all periods, including current ones where the EFP is low.<sup>39</sup>

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<sup>37</sup>Here error bands would have been useful, in the sense that if they had crossed the zero line, they would have cast some doubt on the counter-cyclicality of the premium. The error bands I computed show that the sign of the premium is correct and statistically significant for all the shocks.

<sup>38</sup>Notice the high persistence in investments due to those costs.

<sup>39</sup>This is due to the entrepreneurs' forward looking nature. They know that in the future they are going to pay more, so they also take this into account in the current period. Another interesting demonstration of the entrepreneurs' nature can be seen by analyzing the pick of investments. Since they know that they are going to pay more in the future, they tend to anticipate investments. The pick in

This phenomenon impedes investments from reacting more when financial frictions are operating. In my case investments behaves differently. They are subject to the acceleration mechanism. This can easily be explained by the fact that the EFP becomes pro-cyclical much later than in the De Graeve (2008) case. In fact it takes 12 periods to reverse its sign, vs. the 6-7 of De Graeve (2008).

That is what the models predict on average. I am nevertheless convinced that the decision about the magnitude of the financial accelerator and on its empirical relevance (e.g. investments reacting either more or less after a productivity shock) is an empirical issue. Hence I think that more has to be evaluated, and in particular error bands are fundamental when judging such an issue. As anticipated, I will analyze them in the next section.

Since the investments adjustment costs assumption is crucial, I tried to estimate the model with capital adjustment costs, to check the validity of the argument behind the interaction with the financial frictions. In particular, under capital adjustments costs equation 2 reduces to

$$\widehat{q}_t = \chi (\widehat{i}_t - \widehat{k}_t) + \widehat{x}_t \quad (5)$$

where  $\chi$  is a parameter whose estimated posterior mode is 1.30 in SWFA and 0.92 in SW. Under this set-up a technology shock gives rise to a complete counter-cyclical premium, as in Queijo (2005, 2008). In addition, the log data density is -316.42 in the SWFA model and -323.1 in the other case, giving an empirical argument in favour of the investment adjustment costs.

Finally, the wage mark-up shock is depicted in figure C.11. The mechanism is by now clear, so I will not describe it. What is important to stress is that this shock leads to a pro-cyclical premium.

What lesson is learned from this section? The most relevant shocks driving the premium push it in different directions. Either they make it move in the same direction of output or in the opposite direction. At any point in time they may occur simultaneously, but with different intensity. The behaviour of the premium highlighted in figure C.5 during

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SWFA is reached after 10 periods and in SW after 11. The difference is not huge, but this is due to the large amount of time taken by the EFP to become pro-cyclical, giving entrepreneurs many periods of low burden on their debts. See later in the text.

recessions is then determined by the combination of these forces, and its sign is determined by the dominant shock(s).

### 5.5. Further evidence regarding SWFA

In the previous sections I adduced evidence about the superiority of SWFA over SW. The two main arguments in favour of the former are (1) it better fits the Euro Area data, (2) it generates quite a good series for the premium.

Nevertheless, SWFA has some relevant weak points. The main three are: (1) it is hard to distinguish it from SW on the basis of the second moments of the generated series, (2) the financial accelerator is not statistically significant,<sup>40</sup> (3) uncertainty about the magnitude of the response of the endogenous variables to shocks increases in some cases.

Concerning the first point, standard deviations for the main macroeconomic aggregates are reported in table B.8. They look very similar, making the task of choosing between SWFA and SW difficult. Moreover, this makes a comparison with the observed time series' standard deviations superfluous.

[Table B.8 here]

In figure C.12 I disentangle the last two points. The response of investments to the four shocks analyzed in section 5.4 is represented for both SWFA (black line) and SW (green line) together with the 90% error bands (dashed line). It is evident that responses are not statistically distinguishable because error bands overlap in most cases.<sup>41</sup>

As for the uncertainty, in general SWFA and SW responses are comparable. The uncertainty around the mean responses is similar. Nevertheless, in the case of the monetary policy shock the probability band is larger under SWFA, giving the policy maker less information (i.e. more uncertainty) about that response.

[Figure C.12 here]

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<sup>40</sup>The reader may think that this may be due to the tight parametrization of some steady state values, in particular the EFP. In section 5.6 I will show that results are robust to perturbation to the steady state calibration.

<sup>41</sup>Only the last part of the response to the monetary policy shock displays no overlapping bands. This may allow me to conclude that the SWFA generates more persistence in the investment response. In any case it is not possible to find a statistically relevant difference for the picks.

According to this analysis, the superiority of SWFA over SW seems to vanish, especially from a policy perspective. The extra complexity of SWFA is not compensated by useful results exploitable by the policy maker.

A possible utilization of the EFP would be to use it as an indicator of future evolutions of either the business cycle or inflation. The fact that the EFP is not always counter-cyclical seems to cast doubt on that, especially in terms of business cycle predictions.

This concern is supported by results shown in table B.6. This shows contemporaneous, lagged and future correlations between the EFP and both the output gap from SWFA and SW and inflation under the two models. They confirm that in all cases the EFP is a lagged variable rather than a leading one, meaning that it tends to move more after the output gap and inflation have moved.

[Table B.6 here]

A possible further evaluation of the EFP's predictive content is worked out in section 6. I will use the procedure described in Fisher et al. (2006) and adapted for purposes similar to mine by Coenen et al. (2009). I will provide some results of robustness checks in the next section, before presenting it.

## 5.6. Robustness checks

The robustness check is conducted on two levels. On the one hand it is related to the choice of the prior distributions (their mean and variance, rather than their shape) and on the other hand, it touches the steady state values assumed prior to the estimation.

Concerning the former, most of the priors are taken from Smets and Wouters (2003), hence they do not need a further robustness check. On the contrary I would consider further the two estimated parameters governing the financial frictions, i.e.  $\kappa$  and  $\vartheta^e$ . The latter is not really relevant. Changing it within a reasonable range does not affect results.

What is more relevant is the elasticity of the risk premium. The choice of the prior mean is clearly dictated by the BGG calibrated value and supported by the previous empirical findings. I tried up to a value twice higher (0.1) and four times higher (0.2) and results still hold (posterior modes are 0.072 and 0.1097 and probability intervals are 0.031-0.083

and 0.041-0.184 respectively). A slightly more delicate issue is related to the variance of the prior. Canova and Sala (2009) argue that the posterior of parameters presenting identification problems becomes more diffuse once a more diffuse prior is used. Hence, they suggest using a sequence of prior distributions with larger variances to detect potential identification problems. I used an infinite variance for  $\kappa$ . Hence I estimated the model first imposing a variance of 0.01, obtaining a posterior standard deviation of 0.0068. Assuming a variance of 0.05 leads to a posterior standard deviation of 0.0069.

Turning to the steady state values, the check still refers to the financial sector values. These are two: the steady state risk premium and the steady state capital-net worth ratio. As showed in the BGG appendix, they are highly non-linearly correlated. Hence once one is controlled, the other is controlled as a consequence. The check I did focuses on the premium steady state. I pushed it first to an annual 4% and then to a 6%. The corresponding implied capital-net worth steady state values are 2.25 and 2.44 respectively. Changing the premium also affects  $\kappa$  and hence the mean of the prior distribution. It becomes 0.09 and 0.17 respectively. Results hold in the sense that the estimation still has desirable properties, but of course  $\kappa$  is different, i.e. closer to the new posterior mean. Nevertheless, I think that 2% is a reasonable value for the steady state premium for the Euro Area. An argument in favour of that value, among others, is that for instance in the fourth quarter of 2008, the worst quarter ever of the crisis in terms of spreads, the BBB graded corporate bonds spread was about 4.85% while the AA graded corporate bonds spread was about 1.4%.<sup>42</sup> In addition, Queijo (2008) estimates the steady state risk premium at 3.6, but she highlights that the value is higher than the one reported in De Fiore and Uhlig (2005) for the Euro Area: they report a risk premium on loans of between 1.6 and 2.7%.

## 6. Inflation forecast

In this section I proceed with the evaluation of the forecast content of the EFP. Given the unsatisfactory results of the estimated model in terms of not reproducing the accelerator effect and increasing the uncertainty of the shocks' impact, it is worth making another test,

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<sup>42</sup>See the ECB Monthly Bulletin 03/2009.

because a further failure would seriously harm the interest of this model from a monetary policy perspective.

According to Coenen et al. (2009) I will forecast inflation on the basis of a traditional Phillips curve specification in which the output gap generated by the SWFA model is used as a measure of the economic slack.<sup>43</sup> I will then consider a modified version of the Phillips curve, replacing the output gap with the EFP. Finally, two control models, a random walk and an autoregressive one, will produce benchmark inflation forecasts to be compared with those of the two more structural models.

### 6.1. Forecast evaluation procedure

The forecast procedure is extensively described in Fisher et al. (2006).<sup>44</sup> I report here only the essential part. What I want to forecast is the  $h$ -period (quarter in my case) change in the private consumption deflator  $\pi_{t+h}^h$ . Since I will focus only on the 4-quarter change,<sup>45</sup>  $h$  will always be equal to 4. Hence, I want to forecast

$$\pi_{t+4}^4 = 100 \left[ \left( \frac{P_{t+4}}{P_t} \right) - 1 \right]$$

where  $P_t$  is the price level at time  $t$ .

The forecast is made using several vintages of data, i.e. for rolling samples of 40 quarters in pseudo–real time. In particular I consider 33 vintages, with the initial sample spanning 1985q1–1998q4 and the final sample covering the period 1985q1–2006q4.

The general specification of the model designed to forecast inflation estimated for each vintage,  $v$ , is

$$\pi_{v,t+4}^4 = a_v + b_v(L) \pi_{v,t} + c_v(L) x_{v,t} + \varepsilon_{v,t+4}^4 \quad (6)$$

<sup>43</sup>Output gap is defined as the difference between the current output and the flexible-price level of output  $y_t^*$ .

<sup>44</sup>The authors use the procedure to study the performance of money based inflation forecasts in the Euro Area. Coenen et al. (2009) use the same approach to study the forecast performance of output gap inflation forecasts in the Euro Area.

<sup>45</sup>This choice is motivated by the fact that the choice of the optimal lags of the estimated models (see below in the text) requires a lot of regressions. I think that in any case the choice is fair enough because it is in line with what Fisher et al. (2006) do, since they focus mainly on a single forecast horizon (6 quarters). Moreover, since I am using the same Euro Area data used by Coenen et al. (2009) and my results are pretty much in line with their ones, I am comfortable in arguing that my results may be robust also for other time horizons. I will leave this exercise for the future.

where  $\pi_{v,t} = 400 \left( \frac{P_t}{P_{t-1}} - 1 \right)$  is the annualized one-period change in the private consumption deflator,  $x_{v,t}$  is either the output gap coming from the SWFA model or the EPF, and  $b_v(L)$  and  $c_v(L)$  are finite polynomials of order  $p$  and  $q$  of the form  $b_v(L) = 1 + b_{v1}L + b_{v2}L^2 + \dots + b_{vp}L^p$  and  $c_v(L) = 1 + c_{v1}L + c_{v2}L^2 + \dots + c_{vq}L^q$ .<sup>46</sup> The model is estimated by OLS.

For each data vintage, based on the final specification in 6, a forecast of inflation is obtained<sup>47</sup>

$$\widehat{\pi}_{v,t+4}^4 = a_v^{OLS} + b_v(L)^{OLS} \pi_{v,t} + c_v(L)^{OLS} x_{v,t}$$

The autoregressive model of inflation is estimated following the same procedure described above. The random walk forecast of inflation is given by the average rate of inflation over the previous 4 quarters available for a given data vintage

$$\pi_{v,t+4}^{4,RW} = 100 \left( \frac{P_t}{P_{t-4}} - 1 \right)$$

The comparison of the models is based on the comparison of the Mean Squared Forecast Error (MSFE) given by each of them. To compute this for a generic model  $M$ , the forecast error  $e_t$  is first define as

$$e_{t+4}^{4,M} = \widehat{\pi}_{v,t+4}^{4,M} - \pi_{t+4}^4$$

where  $\pi_{t+4}^4$  is the realized inflation rate in the last available vintage of data.

Estimated bias (*bias*) and variance ( $\sigma^2$ ) of the forecast error are

$$bias^M = \frac{1}{T} \sum_{t=1}^T e_{t+4}^{4,M} \quad (\sigma^M)^2 = \frac{1}{T} \sum_{t=1}^T \left( e_{t+4}^{4,M} - \frac{1}{T} \sum_{t=1}^T e_{t+4}^{4,M} \right)^2$$

where  $T$  is the number of forecast points (33 in my case).

The MSFE is finally given by

$$MSFE^M = (\sigma^M)^2 + (bias^M)^2$$

<sup>46</sup>The optimal number of lags is chosen using the Schwartz information criteria.

<sup>47</sup>To be more explicit,  $\widehat{\pi}_{v,t+4}^4$  is the last fitted value for each OLS regression.

## 6.2. Forecast evaluation results

Table B.9 reports results of the MSFE computations. It is immediately clear that the Phillips curve model with the EFP as a measure of the economic slack is the best model in terms of MSFE. It is not only better than the other specification of the Phillips curve, but it also beats the two control models.<sup>48</sup>

Nevertheless, that model does not provide the best performance in terms of the forecast error variance, since the Phillips curve with the output gap measure guarantees a lower variance. On the contrary, the latter is biased towards an over-prediction of inflation, as clearly appears in figure C.13. In fact the bias is 0.58, much higher than all the others.<sup>49</sup>

[Table B.9 here]

[Figure C.13 here]

## 7. Concluding remarks

In this paper I estimated a New Keynesian Dynamic Stochastic General Equilibrium model following Smets and Wouters (2003, 2005, 2007) featured with financial frictions à la BGG, i.e. featured with the financial accelerator mechanism, for the Euro Area for the period 1980q1 to 2008q3.

The main aim has been to estimate a time series for the unobserved risk premium that entrepreneurs have to pay on their loans given the risky nature of their projects and the asymmetric information that exists between them and the banks providing the funds.

A second important dimension of the analysis is related to the amount of information the estimated EFP can provide about the importance of modeling financial frictions to implement monetary policy taking into account the functioning of the financial markets.

A first analysis of the EFP has shown that financial frictions are a key element to be modeled. In fact, on the one hand, SWFA generates a series for the EFP that is highly

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<sup>48</sup>I would like to stress that since I am using the same data for the Euro Area as Coenen et al. (2009) and I obtain very similar results for the random walk model, but above all for the autoregressive specification, it seems to me that results for the other two models are reliable and maybe robust to other forecast horizons.

<sup>49</sup>The other models have a negative bias, i.e. on average they under-predict inflation.

correlated with some ready-to-use proxies for the premium for the Euro Area (up to 85% with the AAA graded corporate bond spreads). On the other hand, it is indeed able to replicate the end-of-sample financial crisis. Another arguments in favour of SWFA over the model without financial frictions SW is the ability of the former to better describe the Euro Area data. Comparison of the marginal likelihood of the two models allows me to conclude that there is decisive evidence in favour of SWFA.

Nevertheless, SWFA has some relevant weak points. First, it is hard to distinguish it from SW through comparison of the second moments of the series generated by the models, because they are very similar. This enables me to conclude which of the two models generates series closer to the observed ones.

Second, the accelerator effect that SWFA should reproduce turns out to be statistically not significant. The probability bands around the mean impulse response functions overlap for almost all the variables and shocks. This evidently limits the usefulness of the model for policy-making purposes. The statistical irrelevance of the accelerator implies that SWFA does not help the policy maker to have a better understanding of the magnitude of the endogenous variables' mean responses to shocks than does SW, and hence the interest in financial frictions as a feature of the model drops dramatically.

Third, even the uncertainty about the magnitude of the response of the endogenous variables to shocks increases in some cases. Probability bands are larger for the impulse response functions of SWFA, as in the case of the monetary policy shock, the most relevant for the policy authority.

A possible alternative use of the EFP is to consider it as a leading indicator for future evolutions of inflation. Although some evidence would cast some doubt on that property, as for instance the cyclicity found in the premium when technology, investments specific and wage mark-up shocks hit the economy, a more sophisticated approach allowed me to answer the question in the title positively. Yes, the EFP is a useful indicator for monetary policy. In fact, I found that the EFP is a very powerful predictor of inflation. It overcomes, in terms of the Mean Squared Forecast Error, the traditional output gap measure in a Phillips curve specification, and the control models for forecast inflation consisting of a random walk and an autoregressive representation. This also led me to conclude that financial frictions remain a key ingredient to model.

## AppendixA. Steady state values

The steady state value of the return on capital  $R^k$  is

$$R^k = S R^n$$

$$R^k = Re^k + 1 - \delta$$

where  $S = 1.005$  is the steady state level of the finance premium. Remembering that  $R^n = \frac{g_y}{\beta}$ , I can write  $Re^k$  as

$$Re^k + 1 - \delta = S R^n$$

$$Re^k = S \frac{g_y}{\beta} - 1 + \delta$$

The real marginal cost is the inverse of the mark-up

$$MC = \left( \frac{\theta - 1}{\theta} \right)$$

I also know that marginal costs are

$$MC = \left( \frac{1}{1 - \alpha} \right)^{1 - \alpha} \left( \frac{1}{\alpha} \right)^\alpha (Re^k)^\alpha (W)^{1 - \alpha}$$

Solving for  $W$

$$W = \left[ \frac{MC (1 - \alpha)^{1 - \alpha} (\alpha)^\alpha}{(Re^k)^\alpha} \right]^{\frac{1}{1 - \alpha}}$$

From the entrepreneurs's cost minimization problem I have

$$Re^k = \alpha MC \frac{Y}{K} g_y$$

$$W = (1 - \alpha) MC \frac{Y}{L}$$

Combining the two

$$W = (1 - \alpha) \frac{Re^k}{g_y} \frac{1}{\alpha} \frac{Y}{L} \frac{K}{Y}$$

Re-arranging and solving for  $\frac{L}{K}$

$$\frac{L}{K} = \frac{(1 - \alpha) Re^k}{\alpha} \frac{1}{g_y} \frac{1}{W}$$

Profits are

$$\Pi = \lambda_d Y - Re^k K - WL - F$$

where  $\lambda_d$  is the price mark-up. I know that in equilibrium  $Y = Re^k K + WL$ , and that thanks to the fixed cost profits are zero in steady state. Hence.

$$\Pi = \lambda_d Y - Y - F = 0$$

Solving for  $F$

$$F = (\lambda_d - 1) Y$$

which implies that

$$\lambda_d = 1 + \frac{F}{Y} \tag{A.1}$$

But  $Y$  still includes  $F$ . Hence an alternative way to write it is

$$F = (\lambda_d - 1) \left[ \left( \frac{K}{Lg_y} \right)^\alpha L - F \right]$$

Solving again for  $F$

$$F = \frac{\lambda_d - 1}{\lambda_d} \left( \frac{K}{Lg_y} \right)^\alpha L \tag{A.2}$$

Combining equation A.2 with equation A.1 the steady state value of  $Y$  is

$$Y = \frac{1}{\left(1 + \frac{F}{Y}\right)} \left( \frac{K}{Lg_y} \right)^\alpha L$$

Solving for  $\frac{K}{Y}$

$$\frac{K}{Y} = \left( \frac{L}{K} \right)^{\alpha-1} \left( 1 + \frac{F}{Y} \right) g_y^\alpha$$

Using this expression I get  $\frac{I}{Y}$

$$\frac{I}{Y} = \delta \frac{K}{Y}$$

From the resource constraint I can derive an expression for  $C$

$$Y = C + I + G$$

Then

$$C = Y - I - gY$$

where  $g \equiv \frac{C}{Y}$ . Hence

$$g = 1 - \left( \frac{C}{Y} + \frac{I}{Y} \right)$$

Using the production function

$$C = (1 - g) \left[ \left( \frac{K}{L} \right)^\alpha L - F \right] - I$$

Substitute out  $F$  using equation A.2 and  $I$  with its steady state expression  $\delta K$

$$C = (1 - g) \left[ \left( \frac{K}{L} \right)^\alpha L - \frac{\lambda_d - 1}{\lambda_d} \left( \frac{K}{L} \right)^\alpha L \right] - \delta K$$

$$C = (1 - g) \frac{1}{\left(1 + \frac{F}{Y}\right)} \left( \frac{K}{L} \right)^\alpha L - \delta K$$

Or equivalently

$$C = \left[ (1 - g) \frac{1}{\left(1 + \frac{F}{Y}\right)} \left( \frac{K}{L} \right)^\alpha - \delta \frac{K}{L} \right] L$$

Solving for  $\frac{C}{K}$

$$\frac{C}{K} = (1 - g) \frac{1}{\left(1 + \frac{F}{Y}\right)} \left( \frac{L}{K} \right)^{1-\alpha} - \delta$$

The steady state value of capital is given by

$$K = \frac{W(\theta^w - 1)}{\theta^w} \left\{ \left[ (1 - h) \frac{C}{K} \right]^{-\sigma_c} \left( \frac{L}{K} \right)^{-\sigma_L} \right\}^{\frac{1}{\sigma_c + \sigma_L}}$$

As a consequence

$$C = \frac{C}{K} K; \quad I = \delta K; \quad Y = \frac{C + I}{1 - g}; \quad L = \frac{L}{K} K; \quad NW = \frac{NW}{K} K$$

where  $\frac{NW}{K}$  is obtained from the entrepreneur-bank optimal contract's first order conditions.

## Appendix B. Tables

Parameter	Value	Parameter	Value	Parameter	Value
Discount factor ( $\beta$ )	0.99	Capital share on output ( $\alpha$ )	0.3	Payoff lost in bankruptcy ( $\mu$ )	0.12
Goods elasticity of substitution ( $\theta$ )	6	Annualized business failure rate ( $F(\bar{\omega})$ )	0.03	Consumption-output ratio ( $\frac{C}{Y}$ )	0.6
Steady state wage mark-up ( $\lambda_w$ )	3	Annual steady state risk premium ( $R^k - R$ )	0.02	Variance of $\omega$ ( $\sigma_\omega$ )	0.07
Capital depreciation rate ( $\delta$ )	0.025	Capital to net worth ratio ( $\frac{K}{NW}$ )	2	Gross growth rate ( $g_Y$ )	1.0039

Table B.1: Calibrated Parameters.

Support for $M_{SW}$	Very slight evidence against $M_{SW}$	Slight evidence against $M_{SW}$	Strong evidence against $M_{SW}$	Decisive evidence against $M_{SW}$
$B_{SWFA SW} < 1$	$1 < B_{SWFA SW} < 3$	$3 < B_{SWFA SW} < 10$	$10 < B_{SWFA SW} < 100$	$B_{SWFA SW} > 100$

Table B.2: Bayes factor decision rule.

Log data density	SWFA	SW	$B_{SWFA SW}$
Laplace approximation	-296.46	-309.92	$exp^{13.46}$
Harmonic mean	-294.07	-299.01	$exp^{4.94}$

Table B.3: Log data density.

Parameters	Distribution	Prior		Posterior mean		Probability interval		Posterior mean		Probability interval	
		Mean	Std. dev.	SWFA	SW	SWFA	SW	SWFA	SW	SWFA	SW
Std. dev. preference shock ( $\sigma_\beta$ )	Inv. gamma	0.2	Inf	0.3521	0.1772	0.5183	0.3923	0.2043	0.5832	0.2043	0.5832
Std. dev. investment shock ( $\sigma_\lambda$ )	Inv. gamma	1	Inf	0.4201	0.3350	0.5043	0.4401	0.3635	0.5177	0.3635	0.5177
Std. dev. technology shock ( $\sigma_a$ )	Inv. gamma	0.1	Inf	0.6680	0.5431	0.7891	0.7452	0.6108	0.8764	0.6108	0.8764
Std. dev. monetary policy shock ( $\sigma_{\pi d}$ )	Inv. gamma	0.4	Inf	0.1288	0.1120	0.1454	0.1265	0.1106	0.1425	0.1106	0.1425
Std. dev. gov. spending shock ( $\sigma_g$ )	Inv. gamma	0.1	Inf	1.5607	1.2674	1.8328	1.9194	1.4662	2.3512	1.4662	2.3512
Std. dev. wage mark-up shock ( $\sigma_w$ )	Inv. gamma	0.3	Inf	0.1513	0.1090	0.1918	0.1427	0.1067	0.1778	0.1067	0.1778
Std. dev. price mark-up shock ( $\sigma_{\pi^p}$ )	Inv. gamma	0.25	Inf	0.0930	0.0695	0.1167	0.0935	0.0711	0.1161	0.0711	0.1161
Std. dev. unit root tech. shock ( $\sigma_{g^y}$ )	Inv. gamma	0.15	Inf	0.0113	0.0022	0.0185	0.0101	0.0022	0.0185	0.0022	0.0185
Persistence param. preference shock ( $\rho_\beta$ )	Beta	0.85	0.1	0.7885	0.6876	0.8888	0.7554	0.6500	0.8612	0.6500	0.8612
Persistence param. investment shock ( $\rho_\lambda$ )	Beta	0.85	0.1	0.5058	0.3433	0.6664	0.4279	0.2873	0.5628	0.2873	0.5628
Persistence param. technology shock ( $\rho_a$ )	Beta	0.85	0.1	0.9816	0.9661	0.9987	0.9874	0.9755	0.9995	0.9755	0.9995
Persistence param. gov. spending shock ( $\rho_g$ )	Beta	0.85	0.1	0.9330	0.8659	0.9983	0.9653	0.9277	0.9994	0.9277	0.9994
Persistence param. wage mark-up shock ( $\rho_w$ )	Beta	0.85	0.1	0.7788	0.8876	0.9864	0.7884	0.9029	0.9858	0.9029	0.9858
Persistence param. price mark-up shock ( $\rho_{\pi^p}$ )	Beta	0.85	0.1	0.9352	0.6325	0.9319	0.9430	0.6396	0.9459	0.6396	0.9459
Persistence param. unit root tech. shock ( $\rho_{g^y}$ )	Beta	0.85	0.1	0.8539	0.7189	0.9902	0.8521	0.7127	0.9898	0.7127	0.9898
Elasticity of external finance wrt leverage ( $\alpha$ )	Inv. gamma	0.05	Inf	0.0276	0.0118	0.0427	-	-	-	-	-
Entrepreneur's rate of survival ( $\theta^e$ )	Beta	0.975	0.01	0.9769	0.9630	0.9918	-	-	-	-	-
Habit formation ( $h$ )	Beta	0.7	0.05	0.6332	0.5602	0.7059	0.6272	0.5564	0.7007	0.5564	0.7007
Inverse of the elasticity of work effort wrt real wage ( $\sigma_L$ )	Norm	2	0.75	2.3363	1.3415	3.3455	2.5449	1.5230	3.4882	1.5230	3.4882
Inverse of elasticity of substitution in consumption ( $\sigma_c$ )	Norm	1	0.375	1.2209	0.8477	1.6041	1.2503	0.9027	1.6063	0.9027	1.6063
Past wage indexation ( $\tau_w$ )	Beta	0.75	0.15	0.4866	0.2447	0.7275	0.4754	0.2297	0.7147	0.2297	0.7147
Past inflation indexation ( $\tau_\pi$ )	Beta	0.75	0.15	0.1410	0.0533	0.2263	0.1365	0.0514	0.2155	0.0514	0.2155
Calvo wage ( $\xi_w$ )	Beta	0.7	0.05	0.5804	0.4873	0.6665	0.5861	0.5119	0.6598	0.5119	0.6598
Calvo price ( $\xi_\pi$ )	Beta	0.75	0.05	0.7779	0.7307	0.8274	0.7770	0.7314	0.8240	0.7314	0.8240
Inverse elast. of the capital util. cost function ( $\varphi$ )	Norm	4	1.5	6.5355	4.6361	8.4616	6.0579	4.1398	7.8772	4.1398	7.8772
Fix cost over output ( $\phi$ )	Norm	0.45	0.25	0.2240	0.0831	0.3628	0.0562	-0.0591	0.1760	-0.0591	0.1760
Inverse of investment adjustment cost ( $\psi$ )	Norm	0.2	0.075	-0.0938	-0.1796	-0.0097	-0.0873	-0.1818	0.0016	-0.1818	0.0016
Response of interest rate to inflation ( $r_\pi$ )	Norm	1.7	0.1	1.7166	1.5660	1.8643	1.7054	1.5547	1.8555	1.5547	1.8555
Response of interest rate to output ( $r_y$ )	Norm	0.125	0.05	0.0073	-0.0185	0.0333	0.0091	-0.0146	0.0324	-0.0146	0.0324
Smooth parameter in instrument rule ( $\phi_m$ )	Beta	0.8	0.05	0.8451	0.8077	0.8825	0.8450	0.8090	0.8821	0.8090	0.8821
Response of interest rate to output growth ( $r_{\Delta y}$ )	Norm	0.3	0.1	0.3216	0.2451	0.4014	0.3149	0.2394	0.3909	0.2394	0.3909
Response of interest rate to infl. first diff. ( $r_{\Delta \pi}$ )	Norm	0.063	0.05	0.1254	0.0727	0.1766	0.1197	0.0707	0.1688	0.0707	0.1688
Calvo Employment ( $\xi_E$ )	Beta	0.5	0.15	0.7531	0.7196	0.7868	0.7657	0.7349	0.7965	0.7349	0.7965

Table B.4: Prior and posterior distributions. 90% probability intervals are displayed.

	EFP	AAA	AA	A	BBB	Credit standards
Standard deviation	0.036	0.193	0.287	0.270	0.674	0.190
Cross correlations						
2000q1 - 2008q3						
EFP	1					
AAA	0.85	1				
AA	0.73	0.91	1			
A	0.74	0.69	0.74	1		
BBB	0.62	0.74	0.88	0.78	1	
Cross correlations						
2003q1 - 2008q3						
EFP	1					
AAA	0.93	1				
AA	0.78	0.92	1			
A	0.82	0.88	0.86	1		
BBB	0.70	0.86	0.98	0.85	1	
Credit standards	0.44	0.48	0.53	0.78	0.62	1

Table B.5: Standard deviations and cross correlations of EFP and proxies. Credit standards' standard deviation is computed for the period 2003q1-2008q3. The EFP's standard deviation for that period is 0.04.

	EFP	Output gap SWFA	Inflation SWFA	Output gap SW	Inflation SW
Correlations with EFP					
1980q2 - 2008q3					
-6	0.553	0.220	0.228	0.222	0.197
-5	0.635	0.274	0.241	0.278	0.211
-4	0.723	0.322	0.229	0.327	0.200
-3	0.810	0.374	0.184	0.378	0.158
-2	0.891	0.418	0.205	0.422	0.184
-1	0.961	0.445	0.235	0.451	0.220
0	1.000	0.458	0.241	0.465	0.231
1	0.961	0.132	0.131	0.131	0.102
2	0.891	0.045	0.087	0.043	0.060
3	0.810	-0.044	0.025	-0.047	0.000
4	0.723	-0.129	-0.002	-0.132	-0.024
5	0.635	-0.206	-0.099	-0.209	-0.120
6	0.553	-0.272	-0.160	-0.274	-0.178

Table B.6: Correlations between EFP and relevant macroeconomic aggregates.

	$u^x$	$u^\beta$	$u^a$	$u^{ru}$	$u^g$	$u^{\lambda\pi}$	$u^w$	$u^{sy}$
r	6.1	13.29	10.46	42.76	1	7.9	18.44	0.05
c	0.57	1.25	77.34	0.15	2.42	0.26	17.98	0.02
l	3.02	1.23	10.01	1.27	4.12	3.19	77.15	0
inv	7.42	2.9	58.52	0.87	0.06	2.61	27.62	0.01
q	22.98	10.43	23.44	15.13	0.07	16.39	11.56	0
k	3.25	0.92	73.09	0.52	0.04	1.23	20.91	0.05
nw	3.47	1.52	58.84	15.18	0.42	12.25	8.31	0
$r^k$	9.04	5.18	18.93	45.84	0.1	18.16	2.75	0.01
y	0.99	0.31	75.53	0.27	0.51	0.67	21.71	0
$\pi$	6.97	17.76	14.5	16.06	1.47	16.81	26.38	0.05
z	7.68	6.47	36.65	3.99	3.29	21.77	20.06	0.1
mc	4.1	9.3	21.39	4.81	0.41	46.94	13.04	0
S	14.76	2.98	25.98	21.32	2.34	9.88	22.51	0.22
$r^n$	10.88	30.63	29.04	7.79	4.67	4.52	12.28	0.19
w	0.97	0.6	90.68	0.33	0.06	3.07	4.28	0.01
E	0.73	0.17	7.79	0.43	3.85	1.81	85.22	0
$y^*$	0.92	0.52	98.37	0	0.17	0	0	0.02
$\Delta c$	0.79	31.03	40.21	4.76	3.68	1.88	17.64	0.02
$\Delta inv$	59.96	4.93	15.03	1.94	0.05	4.82	13.27	0.01
$\Delta lw$	3.89	10.86	25.55	3.15	0.14	25.46	30.93	0.02
$\Delta ly$	14.38	7.62	37.18	4.29	12.32	3.5	20.68	0.02
$\Delta IE$	6.17	2.31	5.96	2.64	3.54	6.88	72.49	0

Table B.7: Asymptotic variance decomposition SWFA (in percentage) based on posterior means.

	$\pi$	y	w	$r^n$	inv	c	E
Standard deviations SWFA	0.2054	3.5779	1.6151	0.3187	8.136	3.6519	2.1986
Standard deviations SW	0.1968	3.928	2.0871	0.3152	8.2195	4.1265	2.1684

Table B.8: Macroeconomic aggregates' standard deviations under the two specifications of the model.

Model	MSFE	MSFE/RW	MSFE/AR	bias	$\sigma^2$	bias <sup>2</sup>
Phillips curve (output gap)	0.6620	1.2952	0.8895	0.5800	0.3256	0.3364
Phillips curve (premium)	0.4214	0.8245	0.5662	-0.0345	0.4202	0.0012
RW	0.5111	1.0000	0.6868	-0.1746	0.4806	0.0305
AR	0.7442	1.4561	1.0000	-0.1624	0.7178	0.0264

Table B.9: Mean Squared Forecast Errors for the 4 steps ahead inflation forecast.

## Appendix C. Figures

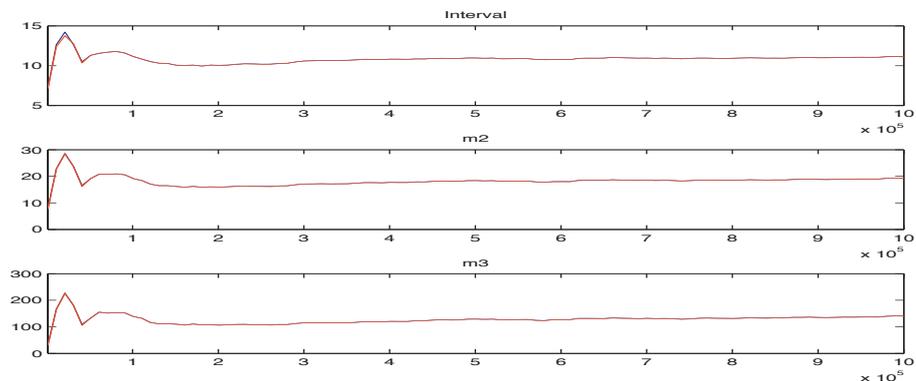


Figure C.1: Overall convergence of the model with financial frictions (SWFA). The red and blue lines represent specific measures of the parameter vectors both within and between chains. For the results to be meaningful, these should be relatively constant and they should converge. Dynare reports three measures: “interval”, being constructed from an 80 per cent confidence interval around the parameter mean, “m2”, being a measure of the variance and “m3” based on third moments. The overall convergence measures are constructed on an aggregate measure based on the eigenvalues of the variance-covariance matrix of each parameter.

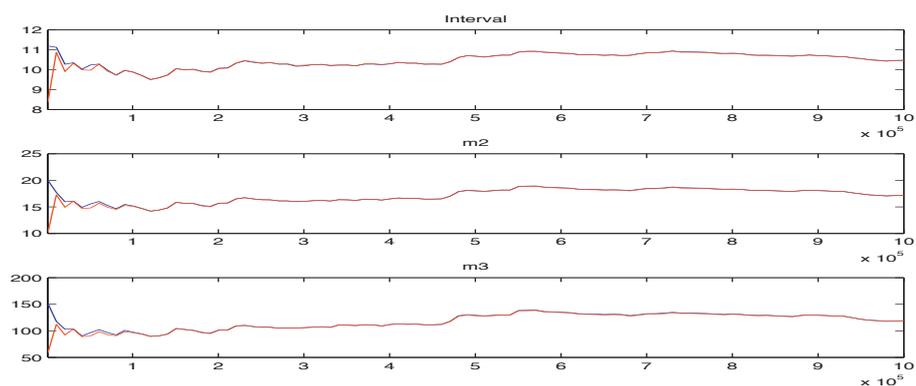


Figure C.2: Overall convergence of the model without financial frictions (SW).

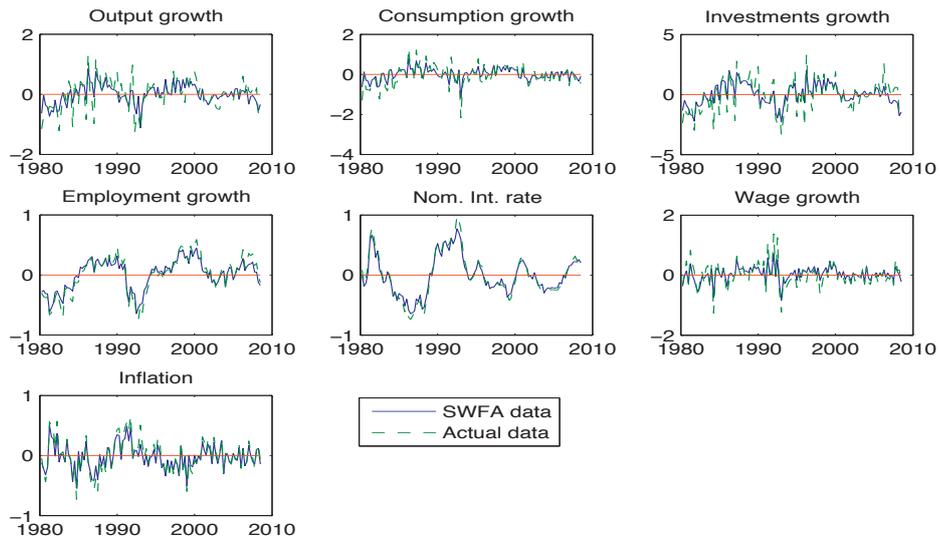


Figure C.3: Data (dashed green line) and fitted values (solid blue line) from SWFA.

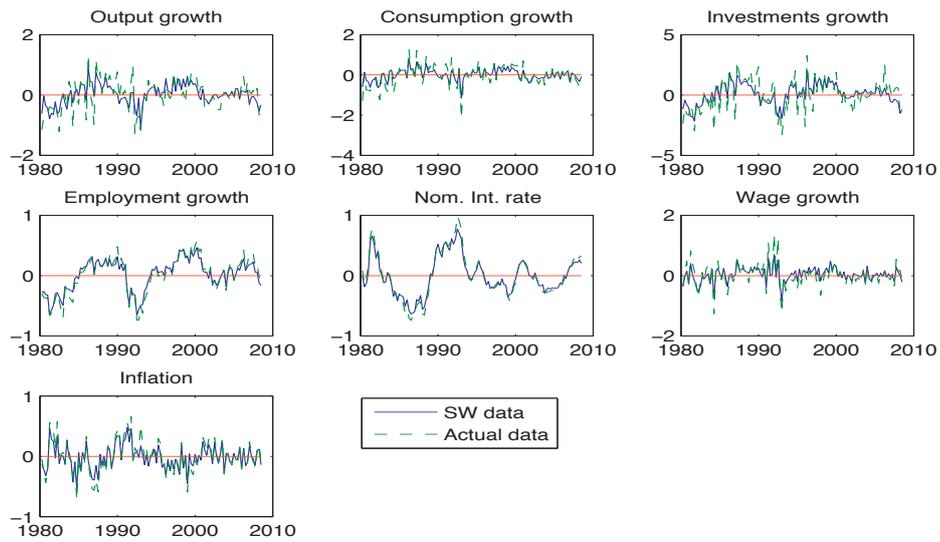


Figure C.4: Data (dashed green line) and fitted values (solid blue line) from SW.

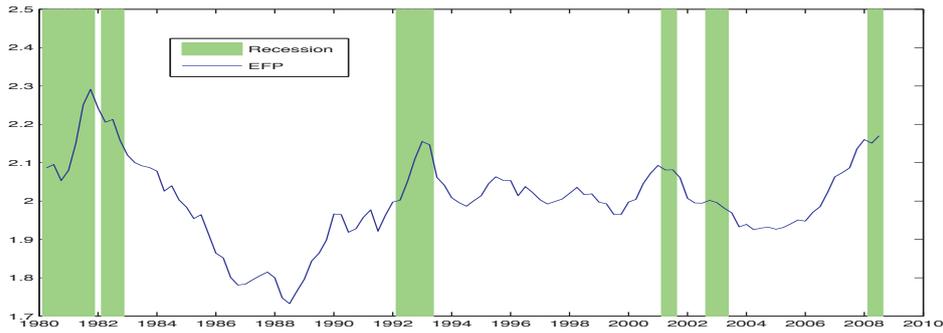


Figure C.5: Series for the EFP generated by SWFA (smoothed values). Percentage values.

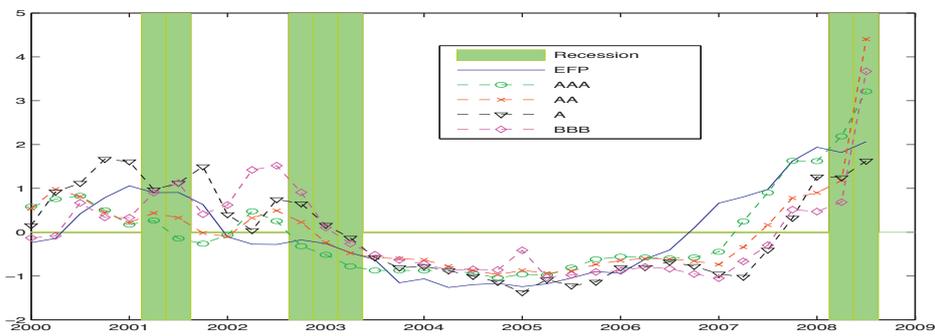


Figure C.6: Comparison of the EFP with the corporate bonds spreads proxies. All series are standardized.

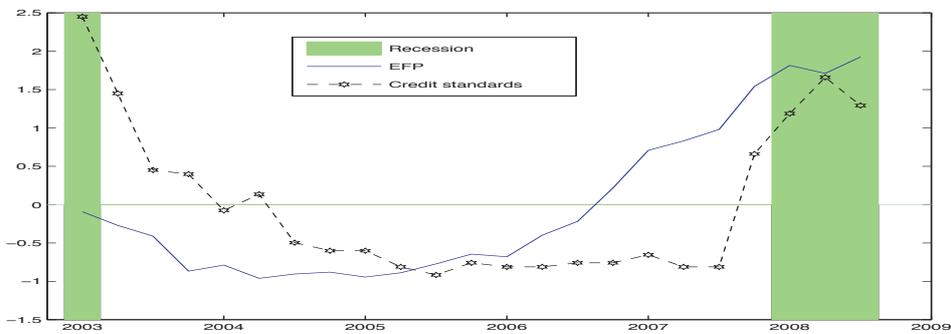


Figure C.7: Comparison of the EFP with the credit standards proxy. All series are standardized.

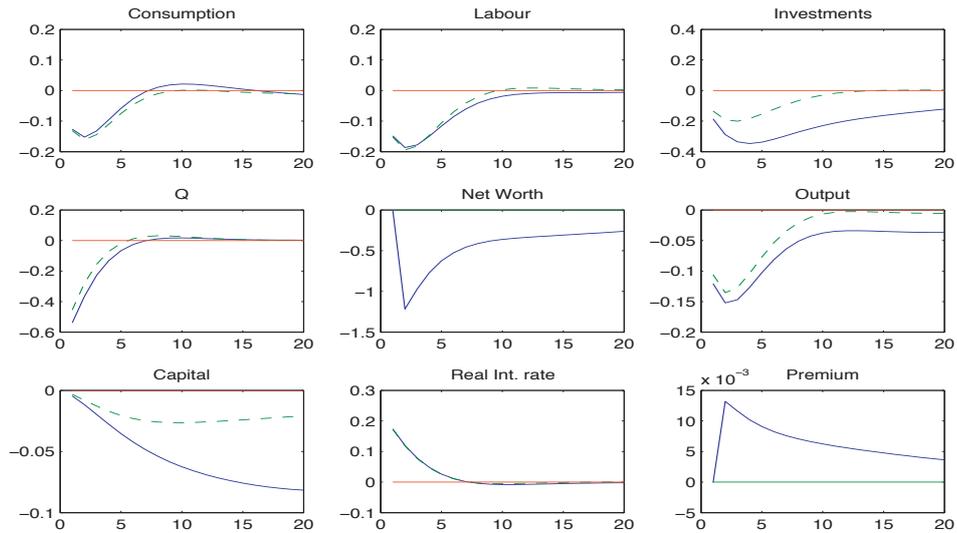


Figure C.8: Mean variables' responses to a one std. dev. orthogonalized monetary policy shock. Percentage deviation from the steady state. Dashed line: SW. Solid line: SWFA.

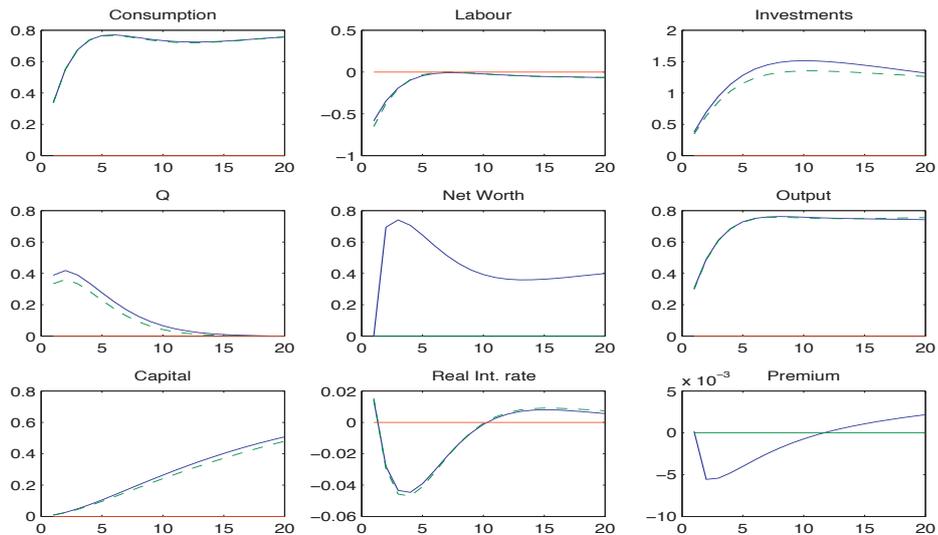


Figure C.9: Mean variables' responses to a one std. dev. orthogonalized technology shock. Percentage deviation from the steady state. Dashed line: SW. Solid line: SWFA.

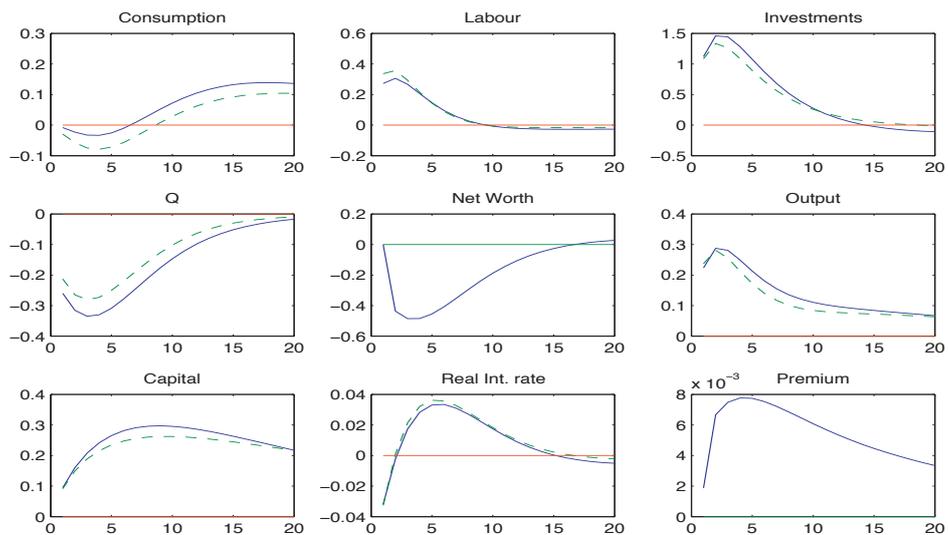


Figure C.10: Mean variables' responses to a one std. dev. orthogonalized investment specific shock. Percentage deviation from the steady state. Dashed line: SW. Solid line: SWFA.

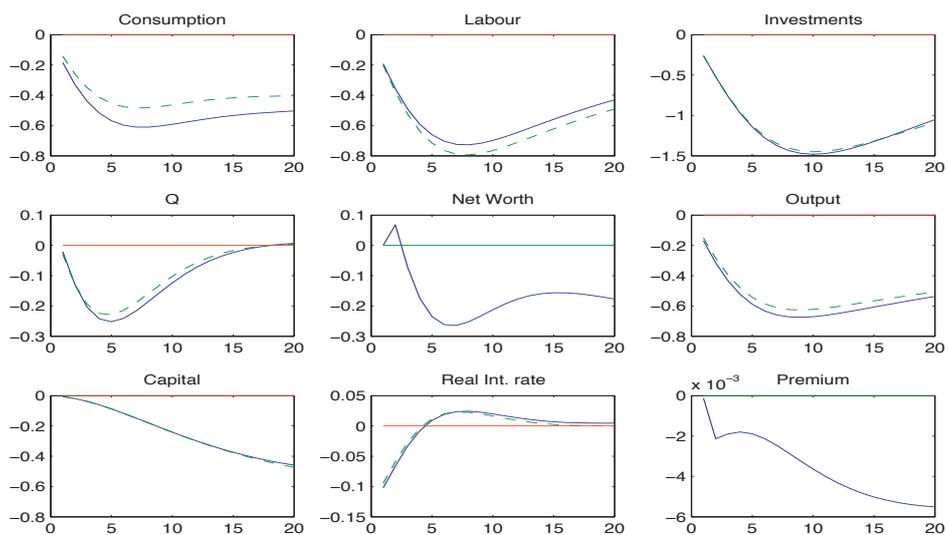


Figure C.11: Mean variables' responses to a one std. dev. orthogonalized wage mark-up supply shock. Percentage deviation from the steady state. Dashed line: SW. Solid line: SWFA.

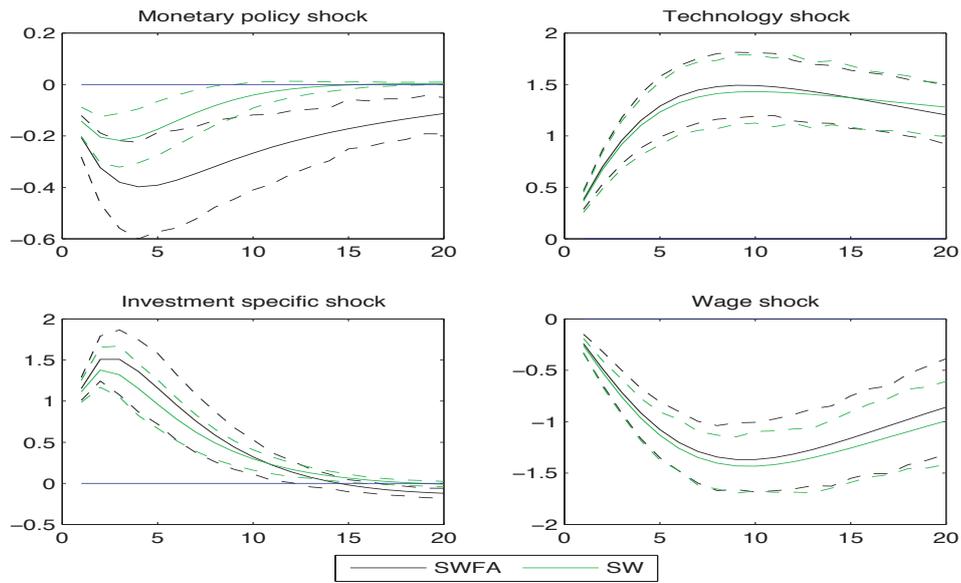


Figure C.12: Investments Bayesian impulse response functions based on posterior modes for the main four shocks; 90% probability bands. Percentage deviation from the steady state.

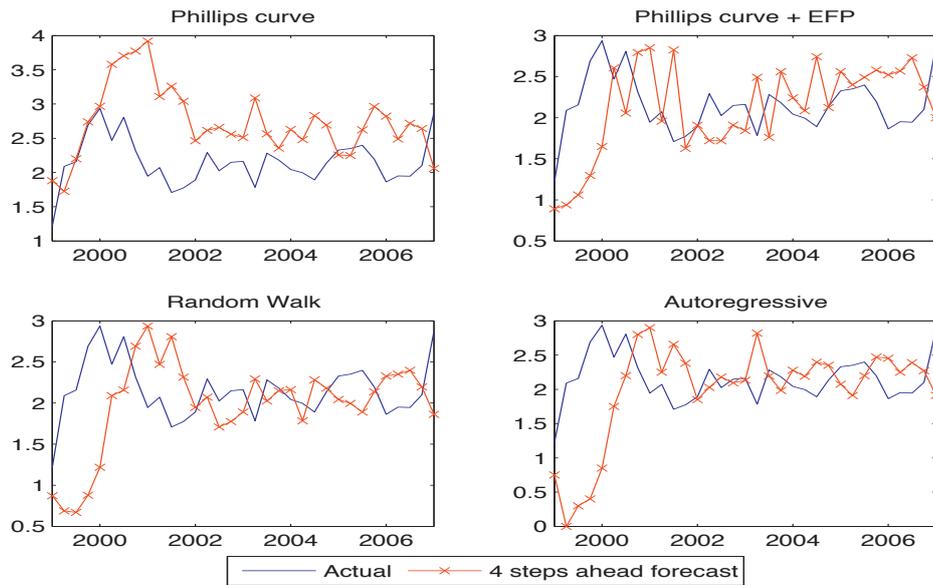


Figure C.13: Four quarters ahead inflation forecast under different models.

## Appendix C.1. Prior and Posterior distributions

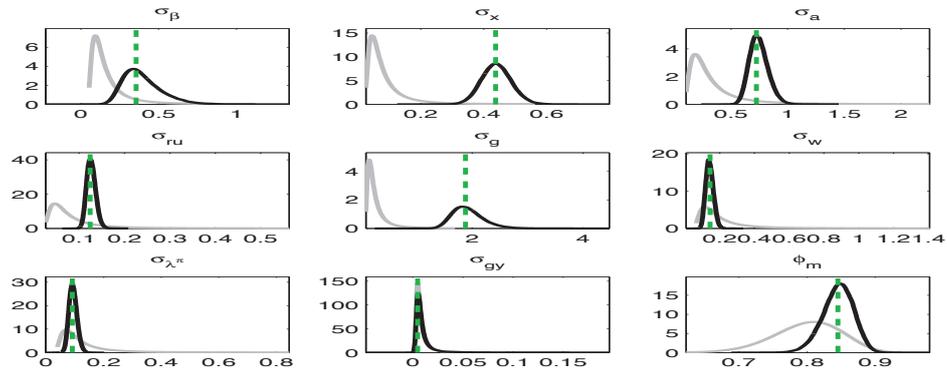


Figure C.14: Posterior distributions SW. The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is the posterior and the brighter one is the prior distribution.

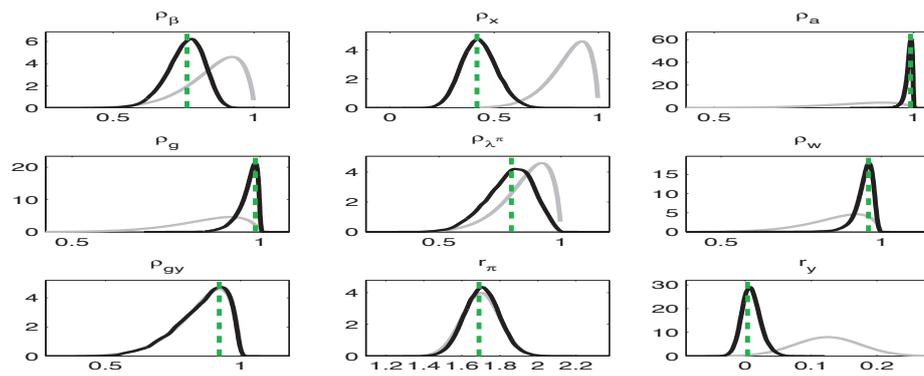


Figure C.15: Posterior distributions SW (contd). The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is the posterior and the brighter one is the prior distribution.

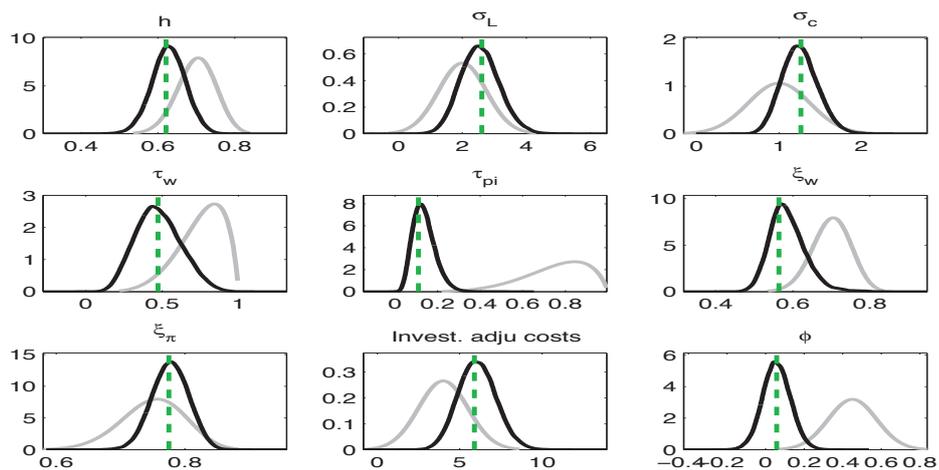


Figure C.16: Posterior distributions SW (contd). The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is the posterior and the brighter one is the prior distribution.

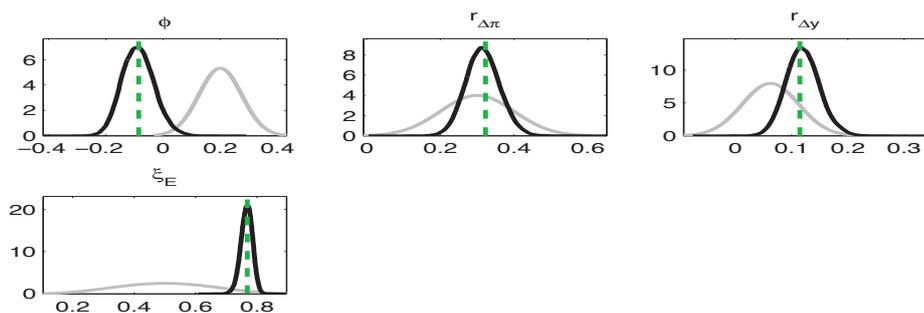


Figure C.17: Posterior distributions SW (contd). The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is the posterior and the brighter one is the prior distribution.

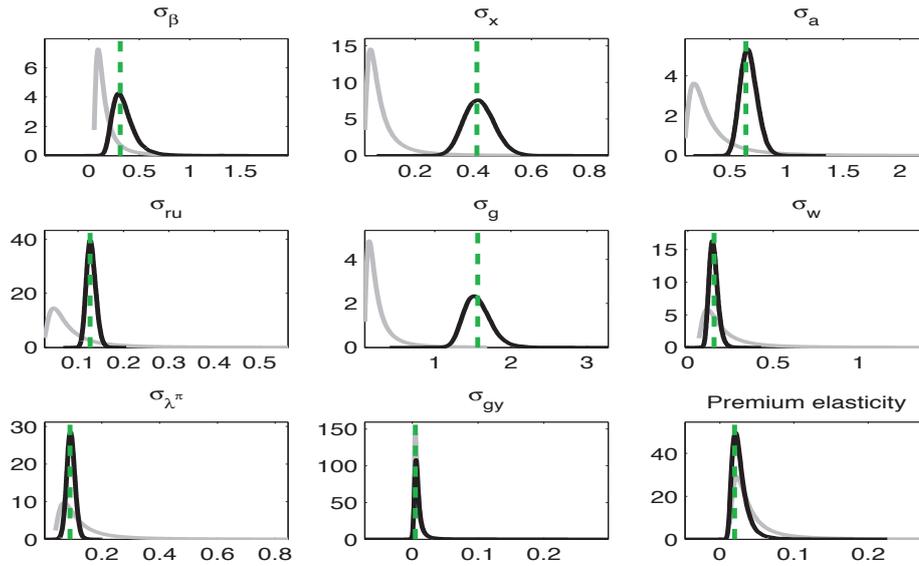


Figure C.18: Posterior distributions SWFA. The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is the posterior and the brighter one is the prior distribution.

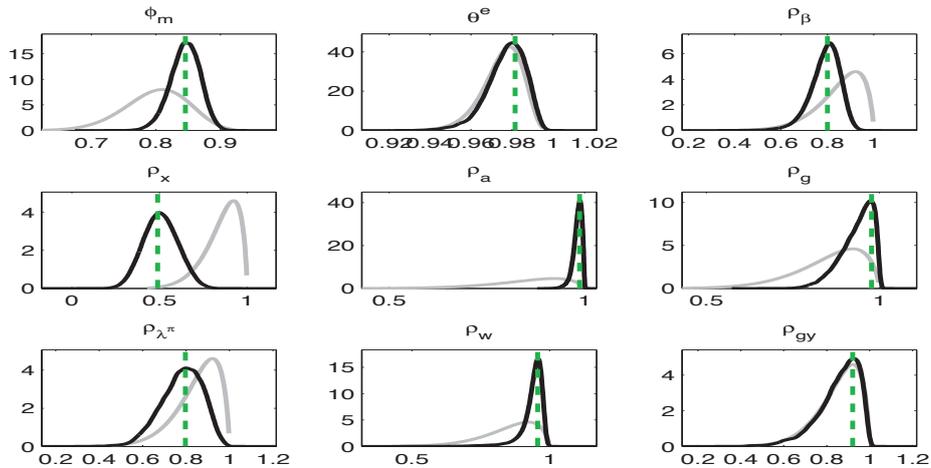


Figure C.19: Posterior distributions SWFA (contd.). The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is the posterior and the brighter one is the prior distribution.

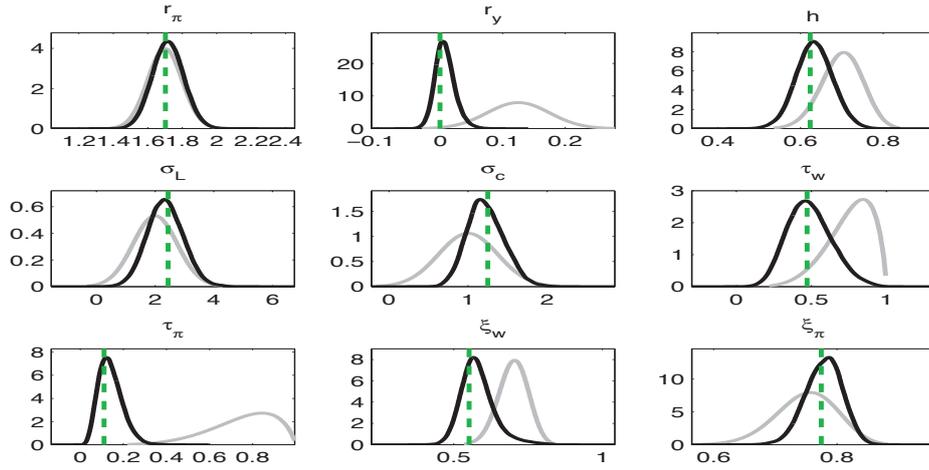


Figure C.20: Posterior distributions SWFA (contd). The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is the posterior and the brighter one is the prior distribution.

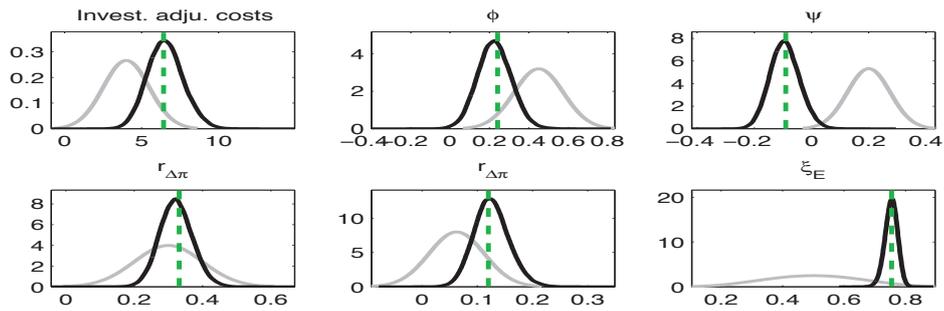


Figure C.21: Posterior distributions SWFA (contd). The green vertical line is the posterior mode obtained from the posterior kernel maximization. The darker distribution is the posterior and the brighter one is the prior distribution.

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