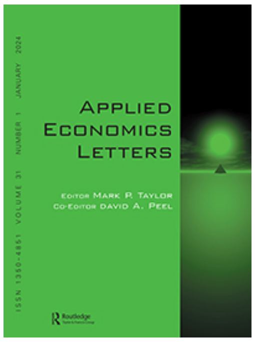

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ARTICLE

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ABSTRACT
We investigate the impact of the financial accelerator on the reaction of asset prices to monetary policy shocks but from the demand side of the economy. In response to a 100-basis point increase in the monetary policy rate, the baseline model shows a stock price reaction of approximately 4.81% without the financial accelerator and of 5.60% with the financial accelerator. This finding is consistent with the financial accelerator literature and the literature on asset prices and monetary policy shocks.

KEYWORDS
Financial accelerator; monetary policy shocks; household portfolio; stock prices

JEL CLASSIFICATION
E32; E37

1. Introduction

This study develops a small-scale new Keynesian (NK) model by introducing the financial accelerator mechanism into the household's portfolio of financial assets. The model is used to investigate how, if introduced from the demand side of the economy, the financial accelerator affects the responses of asset prices to monetary policy shocks. Following on the study by Rigobon and Sack (2004) and Bernanke and Kuttner (2005), the relevant literature has shown that the reaction of asset prices to monetary policy shocks has received significant attention. It is well known that equity prices serve as one of the transmission channels for monetary policy shocks. Thus, shocks that reduce (increase) asset prices affect consumption and output. For example, studies such as those by Bjørnland and Leitemo (2009) and Alessi and Kerssenfischer (2019) have examined the reaction of asset prices to monetary policy shocks. When incorporating asset prices into macro models, scholars usually consider the supply-side interplay between asset prices and the real economy, where asset prices are modelled as the market value of the firm's collaterals.

A study by Castelnuovo and Nisticò (2010) argues that limited attention has been paid to the demand-side channel of incorporating asset prices into NK macro models. However, the demand-side interplay between asset prices and the real economy has recently gained attention in the literature. For instance, Challe and Giannitsarou (2014) use the demand-side interplay to show that the interest rate channel stands as the dominant channel through which monetary policy affects asset prices, while the dividend and the excess return channels play minimal roles. Nonetheless, the role of the financial accelerator in the demand-side interplay between asset prices and the real economy is seriously lacking in the literature. As a result, the focus of this paper, is to contribute to the existing literature by building on the studies by Nisticò (2012) and Challe and Giannitsarou (2014) to demonstrate how the financial accelerator affects the reaction of asset prices to monetary policy shocks.

In line with the study by Aoki et al., (2004), we postulate that the cyclical variations in the price of equity assets held by a household impact on its net worth or its collateral position throughout the business cycle, thus affecting the spread between the interest rate on the household's debts and the riskless interest rate. Some of the debt instruments or liabilities included in the household's portfolio are mortgage loans, car loans, home equity loans, student loans, credit cards, etc. Thus, additional borrowing by the household will be matched by a larger premium if the household's collateral position is weak. This is equivalent to the financial

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accelerator mechanism that is described in the study by Bernanke et al., (1999) but from the perspective of the supply side of the economy. This study quantifies the reaction of asset prices to monetary policy shocks; thus, it compares the findings in terms of the respective conditions, namely with and without the financial accelerator. Our model is calibrated to match the unconditional moments in US data.

The remainder of the paper is structured as follows: Section II presents the model; Section III calibrates and explains the data and the results emanating from the research. Section IV concludes the article.

2. Model

This paper focuses on the description of the model and its linearized version. Step-by-step derivations of the equations in respect of the demand side of the model are presented in Appendix A of this paper. From the demand side of the economy, we assume that the representative household consumes goods and supplies labour to a competitive labour market. The representative household accumulates both financial assets and debts, with access to finance to pay for its additional debts depending on its collateral position. The supply side of the model has been sourced from the study by Galí et al., (2001). The supply side of the model assumes that firms operate in a monopolistic competitive environment where the prices are set as a markup over the marginal costs. The derivation of the hybrid New Keynesian Phillips Curve (NKPC) that we employ here can be found in Appendix A of the paper by Galí et al. (2001). However, the derivation of the real marginal costs is presented in Appendix A of this paper. The relevant equations are presented as follows:

$$\widehat{y}_t = -\frac{1-h}{\chi}\widehat{R}_t + \frac{\sigma}{\chi}E_t\widehat{y}_{t+1} + \frac{\sigma h}{\chi}\widehat{y}_{t-1} + \frac{\gamma\sigma(1+h)}{\chi}\widehat{q}_t + \frac{1-h}{\chi}[\widehat{\varepsilon}_t - E_t\widehat{\varepsilon}_{t+1}] \quad (1)$$

$$\widehat{q}_t = -\frac{1}{1-\gamma}\widehat{R}_t + \frac{\overline{\beta}}{1-\gamma}E_t\widehat{q}_{t+1} + \left(\frac{\gamma\varphi}{1-\gamma}\right)\widehat{y}_t + \frac{1-\overline{\beta}}{1-\gamma}E_t\widehat{d}_{t+1} \quad (2)$$

$$\widehat{\pi}_t = \lambda_a E_t\widehat{\pi}_{t+1} + \lambda_b\widehat{\pi}_{t-1} + \kappa\left\{\left(\frac{\alpha+\sigma_l}{1-\alpha} + \frac{\sigma}{1-h}\right)\widehat{y}_t - \frac{\sigma h}{1-h}\widehat{y}_{t-1} - \frac{1+\sigma_l}{1-\alpha}\widehat{a}_t\right\} \quad (3)$$

$$\widehat{d}_t = \eta_a\widehat{y}_t + \eta_b\widehat{y}_{t-1} + \eta_c\widehat{a}_t \quad (4)$$

$$\widehat{i}_t = \phi_i\widehat{i}_{t-1} + (1-\phi_i)\phi_\pi\widehat{\pi}_t + (1-\phi_i)\phi_y\widehat{y}_t + \widehat{m}_t \quad (5)$$

$$\widehat{R}_t = \widehat{i}_t - E_t\widehat{\pi}_{t+1} \quad (6)$$

where:

$$\chi = \sigma(1+h) - (1-h)\gamma\varphi$$

$$\kappa = \frac{(1-\alpha)(1-\theta)(1-\beta\theta)(1-\omega)}{[1+\alpha(\mu-1)]\{\theta+\omega[1-\theta(1-\beta)]\}}, \lambda_a = \frac{\beta\theta}{\{\theta+\omega[1-\theta(1-\beta)]\}}, \lambda_b = \frac{\omega}{\{\theta+\omega[1-\theta(1-\beta)]\}}$$

The first Equation (1) describes the dynamics of the output gap $\hat{y}_t$, while Equation (2) shows the dynamics of the asset price gap $\hat{q}_t$. Equation (3) represents the NKPC (or inflation), while the real dividend $\hat{d}_t$ is presented in Equation (4). The monetary policy rule is presented in Equation (5), and the real expected interest rate is presented in Equation (6). On the demand side of the economy, σ is the intertemporal elasticity of substitution, σ_l is the inverse of the Frisch elasticity of labour, h stands for habit persistence, β is the discount factor, and φ is the sensitivity of net worth to changes in the output. Parameter γ is the elasticity of the external finance premium (EEFP). In other words, γ captures the financial accelerator effect. Thus, setting $\gamma = 0$ leads to the version of the model without the financial accelerator. On the supply side of the economy, θ measures the degree of price stickiness and ω, the degree of backward indexing, while μ stands for goods elasticity of substitution, $1-\alpha$ measures the output elasticity of labour. In Equation (5), ϕ_i is the interest rate smoothing parameter, ϕ_π measures the reaction to inflation, ϕ_y measures the reaction to the output gap, and $\hat{m}_t$ represents the monetary policy shock. The other two exogenous processes are the preference shock $\hat{\varepsilon}_t$ and the technology shock $\hat{a}_t$.

3. Calibration and results

This paper focuses mainly on the dynamics of output gap, inflation, the stock price gap, and the real expected interest rate. We collected data concerning these variables from the Reserve Bank of Saint Louis Database (FRED) for the period 1961Q1 to 2019Q4. The model has been calibrated to match the unconditional moments of these variables using US data, with the calibrated parameters presented in Table 1. Our calibration of the benchmark value of the external finance premium reflects the estimate in the paper by Christensen and Dib (2008). The values of the other parameters are standard in the literature. Given the objective of the study, we present only the impulses for monetary policy shocks and test whether the results hold true for technology shocks. The impulses for monetary policy shocks are presented for the baseline model (Model A, Figure 1) and two additional variants (Model B, Figure 2; Model C, Figure 3). Table 2 shows the results in terms of the asset price multipliers.

The baseline model (Model A) shows that the stock price gap reacts by approximately 4.81% in

Table 1. Calibration.

Parameter	α	θ	ω	β	γ	σ_l	σ	ϕ_i	ϕ_y	ϕ_π	μ	h
Model A	0.30	0.75	0.50	0.9928	0.0420	2.5	2.5	0.84	0.125	1.50	21	0.80
Model B		0.0001										
Model C												0.00
				Standard deviation of shocks				Persistence of shocks				
Monetary policy				0.0025				0.85				
Technology shocks				0.005				0.95				
Preference shocks				0.015				0.85				

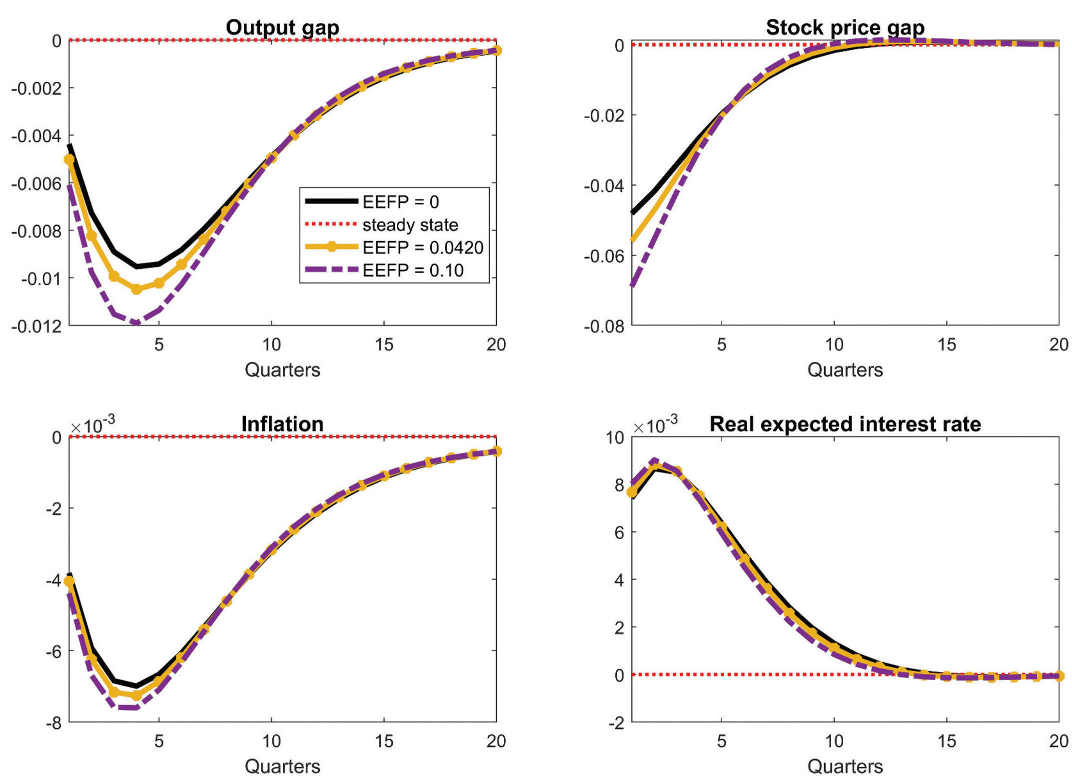

Figure 1. Model A.

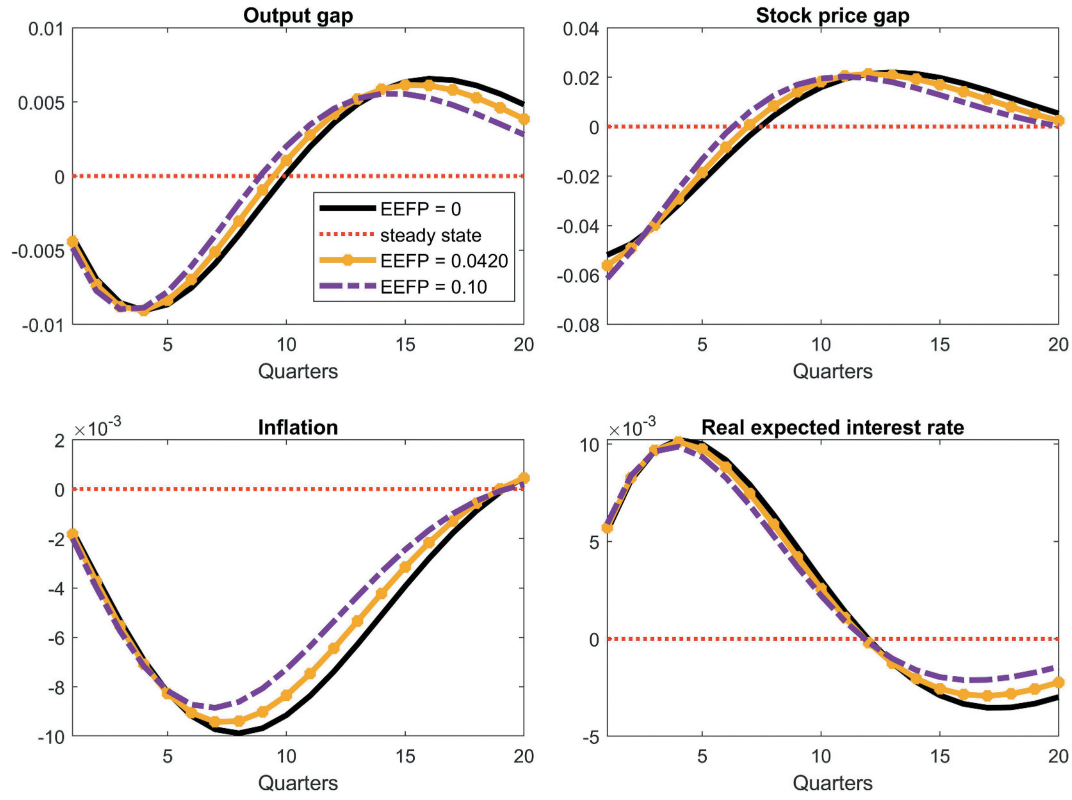

Figure 2. Model B.

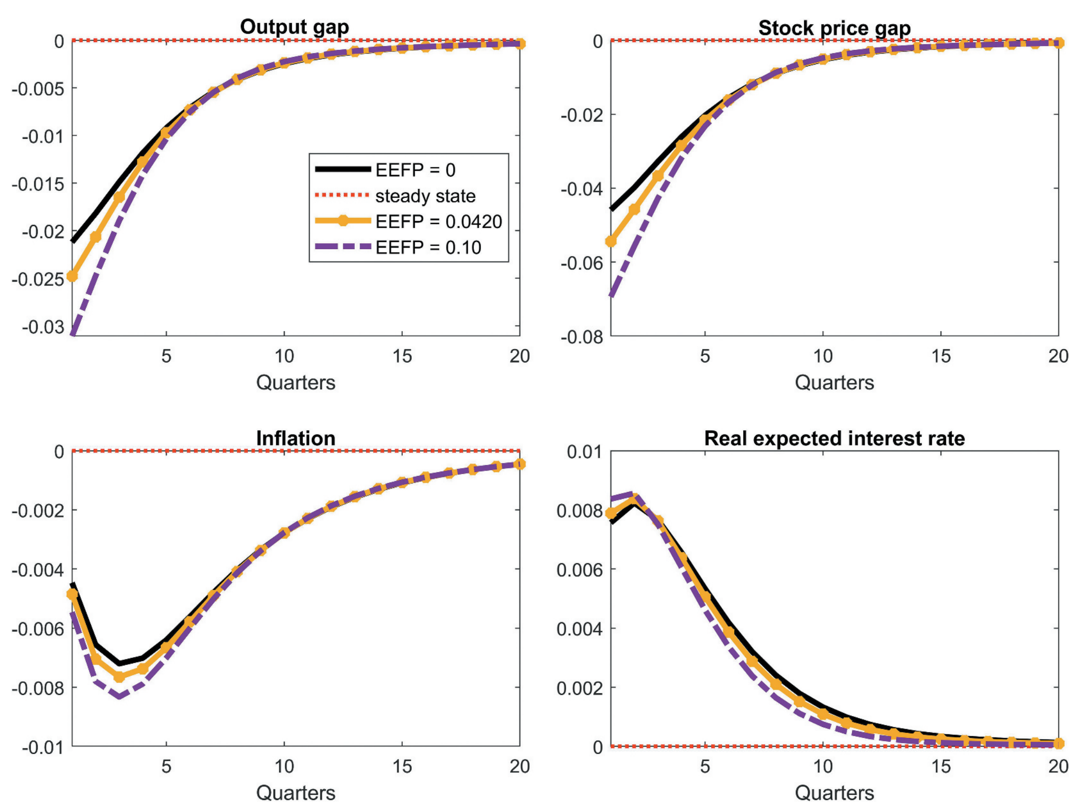

Figure 3. Model C.

Table 2. Stock price multiplier.

	Multipliers for different values of γ		
Elasticity of the external finance premium	$\gamma = 0$	$\gamma = 0.0420$	$\gamma = 0.10$
Baseline model (A)	−4.81	−5.60	−6.90
Flexible price model (B)	−5.19	−5.61	−6.14
Model without habit formation (C)	−4.49	−5.54	−6.94

Note: Like Challe and Giannitsarou (2014), we have reported the immediate responses of the stock price as raw numbers. For instance, in the case of the baseline model (A), an impact increase of 0.0025 of the nominal policy rate leads to an immediate decline of the stock price by approximately −0.0481. This is interpreted as a −4.81% decline of the stock price in response to a 100-basis points surprise increase of the annualized nominal policy rate.

absolute value at $\gamma = 0$ and 5.60% when $\gamma = 0.0420$. Model B generates a multiplier of 5.19% when $\gamma = 0$ and 5.61% when $\gamma = 0.0420$. Similarly, Model C generates a multiplier of 4.49% when $\gamma = 0$ and 5.54% when $\gamma = 0.0420$. The main conclusion from these results is that the financial accelerator amplifies the reaction of asset prices and output to monetary policy shocks. This finding is also reflected in the volatilities of the output gap and the stock price gap

Table 3. Statistics from data and the model.

		Standard deviation				Persistence			
		σ_y	σ_q	σ_π	σ_R	ρ_y	ρ_q	ρ_π	ρ_R
Data		1.45	9.70	2.19	2.48	0.90	0.85	0.98	0.94
Baseline model (A)	$\gamma = 0$	2.54	8.50	1.81	1.89	0.97	0.82	0.96	0.91
	$\gamma = 0.0420$	2.73	9.46	1.85	1.88	0.96	0.80	0.96	0.90
	$\gamma = 0.10$	3.02	11.01	1.91	1.87	0.96	0.77	0.96	0.89
Flexible price model (B)	$\gamma = 0$	2.79	11.25	2.93	2.68	0.96	0.87	0.98	0.95
	$\gamma = 0.0420$	2.65	11.17	2.74	2.54	0.95	0.84	0.98	0.95
	$\gamma = 0.10$	2.47	11.09	2.51	2.40	0.94	0.80	0.98	0.94
Model without habit formation (C)	$\gamma = 0$	3.74	8.34	1.78	1.73	0.81	0.83	0.95	0.89
	$\gamma = 0.0420$	4.17	9.44	1.85	1.71	0.80	0.81	0.95	0.88
	$\gamma = 0.10$	4.92	11.33	1.96	1.68	0.77	0.78	0.94	0.86

Note: σ_j is the standard deviation, and ρ_j stands for first order autocorrelation or persistence.

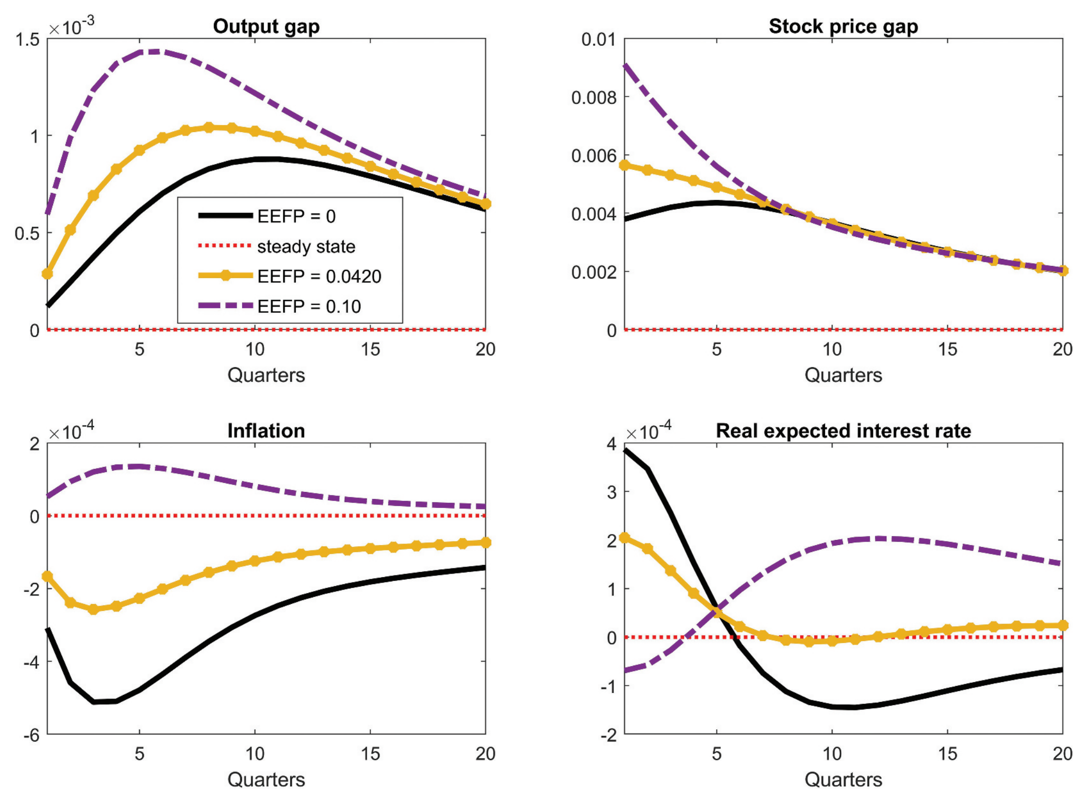

Figure 4. Impulses for technology shocks.

as presented in Table 3. The results are consistent with the findings in the financial accelerator literature. The multipliers generated by the baseline model and its variants are consistent with the ones presented by Bjørnland and Leitemo (2009) and Challe and Giannitsarou (2014).

We also present the impulses of the baseline model for technology shocks in Figure 4. The results continue to still demonstrate that the financial accelerator amplifies the response of asset prices and output to technology shocks. Furthermore, our baseline model with $\gamma = 0.0420$closely matches the unconditional moments in the data. For instance, the volatility of the asset price gap is 9.70% in the data, while our baseline model generates a value of 9.46%. In addition, the model describes well the persistence of the variables.

4. Conclusion

This paper examines how, if introduced from the demand side of the economy, the financial accelerator affects the reaction of asset prices to monetary policy shocks. Our NK model with the financial accelerator shows findings consistent with the financial accelerator literature and the literature that has quantified the reaction of asset prices to monetary policy shocks.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix A.

1. Demand side

Households consume goods and supply labour in a competitive labour market, which earns them a real competitive wage. They maximize utility by applying the following utility maximization technology:

$$U_t(C_t, N_t) = \varepsilon_t \left[\frac{(C_t - hC_{t-1})^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\sigma_l}}{1+\sigma_l} \right] \tag{A.1}$$

where C_t is consumption, N_t is labour, ε_t is a preference shock, σ is the intertemporal elasticity of substitution, h is habit formation in consumption, and σ_l is the inverse of Frisch elasticity of labour. Households accumulate financial assets and debts, that is, they invest in equity shares and accumulate debts. For instance, households can borrow to invest in housing, accumulate car loans, or hold credit cards. With that said, the budget constraint can be written as follows:

$$\frac{P_{kt}}{P_t} k_t - \frac{B_t}{P_t} = \left(\frac{P_{kt}}{P_t} + \frac{D_t^n}{P_t} \right) k_{t-1} - \frac{(1+i_{t-1})(1+\rho_{t-1})B_{t-1}}{P_t} + \frac{W_t}{P_t} N_t - C_t \tag{A.2}$$

where the left-hand side of the budget constraint in Equation (A.2) captures the household's net worth, which is assets minus liabilities, the variable k_t is equity shares, and B_t stands for the household's debt. The nominal price of the equity share is P_{kt}, and the real price of equity is $\frac{P_{kt}}{P_t}$, which will assume the form Q_t in the remainder of the document. The variable $\frac{D_t^n}{P_t}$ is the real dividend, which will assume the form D_t in the remainder of the document. The variable W_t is the nominal wage a household earns by supplying labour to a competitive labour market and i_t is the nominal interest rate. The variable ρ_t is the external finance premium. In this case, additional borrowing by the household depends on its net worth. In other words, additional borrowing by the household requires a premium, where the size of the premium depends on the household's net worth. This implies that the external finance premium is high when the household's net worth is low. The term $(1+i_{t-1})(1+\rho_{t-1})$ shows that the interest rate on the debt instrument held by the household is simply a premium over the risk-free interest rate on short-term bonds. The variable i_t is the nominal short term interest rate and ρ_t is the risk premium or the external finance premium.

Our study is similar in spirit to the study by Aoki et al. (2004) and even assumes some of the assumptions described in their paper. When studying the financial accelerator effect on the housing market, some of the noted assumptions in the afore-mentioned study (Aoki et al., 2004) are that the cyclical variations in the housing price impact on the net worth of the household or its collateral position throughout the business cycle. Second, they note that the household's net worth drives the spread between the mortgage rate and the riskless interest rate. These assumptions also apply to our model. However, in our case, we do not focus on the housing market since households accumulate different types of debts. For instance, households hold mortgage loans, car loans, home equity loans, student loans, credit cards, etc. Thus, the average spread they face is determined by the debt instruments they hold.

Knowing that the household's net worth drives the variations in the external finance premium, the relationship between the gross risk premium and the household's net worth can be written as follows:

$$(1+\rho_t) = \rho\left(\frac{P_{kt}k_t}{B_t}\right) = \left(\frac{P_{kt}}{P_t} . \frac{P_t k_t}{B_t}\right)^{-\gamma} \tag{A.3}$$

In Equation (A.3), $\frac{P_{kt}k_t}{B_t}$ is the household's net worth and γ is the elasticity of the external finance premium. The negative sign captures the financial accelerator mechanism as described in the Bernanke et al. (1999) study. The financial accelerator literature often assumes a procyclical net worth. Thus, we follow Aoki et al. (2004) and Christensen and Dib (2008) and assume that the household's net worth is procyclical to output. This assumption allows us to rewrite Equation (A.3) as follows:

$$(1+\rho_t) = \left(Q_t . \frac{P_t k_t}{B_t}\right)^{-\gamma} = (Q_t f(Y_t))^{-\gamma} \tag{A.4}$$

In Equation (A.4), Y_t is the real output. Given the description provided above, the budget constraint in Equation (A.2) can be rewritten as follows:

$$Q_t k_t - \frac{B_t}{P_t} = (Q_t + D_t)k_{t-1} - \frac{(1+i_{t-1})(1+\rho_{t-1})B_{t-1}}{P_t} + \frac{W_t}{P_t} N_t - C_t \tag{A.5}$$

Using the utility maximizing technology in Equation (A.1) and the budget constraint in Equation (A.5), the first order conditions for consumption, labour, debt, and equity shares are presented as follows:

$$\varepsilon_t (C_t - hC_{t-1})^{-\sigma} = \vartheta_t \tag{A.6}$$

$$\frac{\varepsilon_t N_t^{\sigma_l}}{\vartheta_t} = \frac{W_t}{P_t} \tag{A.7}$$

$$\beta E_t \left(\frac{(1+i_t)(1+\rho_t)}{1+\pi_{t+1}} \right) \vartheta_{t+1} = \vartheta_t \tag{A.8}$$

$$Q_t \vartheta_t = \beta E_t (Q_{t+1} + D_{t+1}) \vartheta_{t+1} \tag{A.9}$$

where ϑ_t is the Lagrangian multiplier. Using the first order conditions in Equations (A.6) and (A.8), the linearized consumption Euler equation is presented as follows:

$$\hat{c}_t = -\frac{1-h}{\sigma(1+h)}\left(\hat{i}_t - E_t\hat{\pi}_{t+1} + \hat{\rho}_t\right) + \frac{1}{(1+h)}E_t\hat{c}_{t+1} + \frac{h}{(1+h)}\hat{c}_{t-1} + \frac{1-h}{\sigma(1+h)}\left[\hat{\varepsilon}_t - E_t\hat{\varepsilon}_{t+1}\right] \tag{A.10}$$

Following the new Keynesian literature, we assume that $\hat{y}_t = \hat{c}_t$, which yields the following linearized output gap equation.

$$\hat{y}_t = -\frac{1-h}{\sigma(1+h)}\left(\hat{i}_t - E_t\hat{\pi}_{t+1} + \hat{\rho}_t\right) + \frac{1}{(1+h)}E_t\hat{y}_{t+1} + \frac{h}{(1+h)}\hat{y}_{t-1} + \frac{1-h}{\sigma(1+h)}\left[\hat{\varepsilon}_t - E_t\hat{\varepsilon}_{t+1}\right] \tag{A.11}$$

Using Equation (A.4), the linearized external finance premium is presented as follows:

$$\widehat{\rho}_t = -\gamma\left(\widehat{q}_t + \varphi\widehat{y}_t\right) \tag{A.12}$$

In Equation (A.12), φ captures the sensitivity of net worth to changes in the output. We now insert Equation (A.12) into equation (A.11) to obtain the following reformulated dynamics of the output gap:

$$\hat{y}_t = -\frac{1-h}{\sigma(1+h)-(1-h)\gamma\varphi}\left(\hat{i}_t - E_t\hat{\pi}_{t+1}\right) + \frac{\sigma}{\sigma(1+h)-(1-h)\gamma\varphi}\left(E_t\hat{y}_{t+1} + h\hat{y}_{t-1}\right) + \frac{\gamma\sigma(1+h)}{\sigma(1+h)-(1-h)\gamma\varphi}\hat{q}_t + \frac{1-h}{\sigma(1+h)-(1-h)\gamma\varphi}\left(\hat{\varepsilon}_t - E_t\hat{\varepsilon}_{t+1}\right) \tag{A.13}$$

If we denote $\sigma(1+h)-(1-h)\gamma\varphi = \chi$, Equation (A.13) can be rewritten as follows:

$$\hat{y}_t = -\frac{1-h}{\chi}\left(\hat{i}_t - E_t\hat{\pi}_{t+1}\right) + \frac{\sigma}{\chi}E_t\hat{y}_{t+1} + \frac{\sigma h}{\chi}\hat{y}_{t-1} + \frac{\gamma\sigma(1+h)}{\chi}\hat{q}_t + \frac{1-h}{\chi}\left(\hat{\varepsilon}_t - E_t\hat{\varepsilon}_{t+1}\right) \tag{A.14}$$

Equation (A.14) is equal to Equation (A.11) when $\gamma = 0$. We linearize the first-order condition in Equation (A.9) and substitute for the linearized version of the external finance premium to obtain the asset price equation. The linearized asset price equation is presented as follows:

$$\widehat{q}_t = -\frac{1}{1-\gamma}\left(\widehat{i}_t - E_t\widehat{\pi}_{t+1}\right) + \frac{\overline{\beta}}{1-\gamma}E_t\widehat{q}_{t+1} + \frac{\gamma\varphi}{1-\gamma}\widehat{y}_t + \frac{1-\overline{\beta}}{1-\gamma}E_t\widehat{d}_{t+1} \tag{A.15}$$

At $\gamma = 0$, Equation (A.15) becomes:

$$\widehat{q}_t = -\left(\widehat{i}_t - E_t\widehat{\pi}_{t+1}\right) + \overline{\beta}E_t\widehat{q}_{t+1} + \left(1-\overline{\beta}\right)E_t\widehat{d}_{t+1} \tag{A.16}$$

Equation (A.16) describes the asset price equation without the financial accelerator.

2. Supply side

The supply side of the model is standard in the literature and is built on the study by Galí et al. (2001). The derivation of the hybrid New Keynesian Phillips Curve (NKPC) employed here can be found in Appendix A of the paper by Galí et al. (2001). Similar to Castelnuovo (2012), the supply side of the model assumes that firms operate in a monopolistic competitive environment and use the following technology to produce goods.

$$Y_t = A_t N_t^{1-\alpha} \tag{A.17}$$

In the production function in Equation (A.17), N_t is labour, and A_t is technology. In setting their nominal prices, firms follow the method in Calvo (1983). That is, prices are fixed for a period of $\frac{1}{1-\theta}$, where the parameter θ is the degree of price rigidity and $1-\theta$ is the probability that a firm would reset its nominal price. Furthermore, we assume that only a proportion of firms set prices optimally when setting the optimal price. A fraction $(1-\omega)$ follows the process of optimal price-setting while the fraction ω uses the backward indexation. In other words, the parameter ω measures the degree of price indexation. Thus, the NKPC that emanates from the environment is the one presented in Galí et al. (2001). The NKPC is therefore presented as follows:

$$\widehat{\pi}_t = \lambda_a E_t\widehat{\pi}_{t+1} + \lambda_b\widehat{\pi}_{t-1} + \kappa\widehat{mc}_t \tag{A.18}$$

$$\kappa = \frac{(1-\alpha)(1-\theta)(1-\beta\theta)(1-\omega)}{[1+\alpha(\mu-1)]\{\theta+\omega[1-\theta(1-\beta)]\}}, \lambda_a = \frac{\beta\theta}{\{\theta+\omega[1-\theta(1-\beta)]\}}, \lambda_b = \frac{\omega}{\{\theta+\omega[1-\theta(1-\beta)]\}}$$

In addition to the degree of the price stickiness and the price indexation parameters in Equation (A.18), the parameter μ stands for the elasticity of substitution between goods. The last term on the right-hand side of Equation (A.18) is the real marginal cost. The total cost of production is made up of labour costs only; thus, when using the production function in Equation (A.17), the total cost of production is written as follows:

$$TC_t = \frac{W_t}{P_t}N_t = \frac{W_t}{P_t}A_t^{-\left(\frac{1}{1-\alpha}\right)}Y_t^{\left(\frac{1}{1-\alpha}\right)} \tag{A.19}$$

Equation (A.19) is used to derive the real marginal cost of production as follows:

$$MC_t = \frac{W_t}{P_t(1-\alpha)}A_t^{-\left(\frac{1}{1-\alpha}\right)}Y_t^{\left(\frac{\alpha}{1-\alpha}\right)} \tag{A.20}$$

Equation (A.20) is used to obtain the linearized real marginal cost equation, which is presented as follows:

$$\widehat{mc}_t = \frac{\alpha}{1-\alpha}\widehat{y}_t + \widehat{w}_t - \frac{1}{1-\alpha}\widehat{a}_t \quad \text{(A.21)}$$

We use the first-order condition in Equation (A.7), the production function in Equation (A.17), and assuming that $\hat{y}_t = \hat{c}_t$, the linearized real wage equation can be written as follows:

$$\widehat{w}_t = \left(\frac{\sigma_l}{1-\alpha} + \frac{\sigma}{1-h}\right)\widehat{y}_t - \frac{\sigma h}{1-h}\widehat{y}_{t-1} - \frac{\sigma_l}{1-\alpha}\widehat{a}_t \quad \text{(A.22)}$$

We use Equation (A.22) to rewrite the real marginal cost function in Equation (A.21) as follows:

$$\widehat{mc}_t = \left(\frac{\alpha+\sigma_l}{1-\alpha} + \frac{\sigma}{1-h}\right)\widehat{y}_t - \frac{\sigma h}{1-h}\widehat{y}_{t-1} - \frac{1+\sigma_l}{1-\alpha}\widehat{a}_t \quad \text{(A.23)}$$

The linearized real marginal cost in Equation (A.23) is used to rewrite the NKPC in Equation (A.18) as follows:

$$\begin{aligned}\widehat{\pi}_t = {} & \lambda_a E_t\widehat{\pi}_{t+1} + \lambda_b\widehat{\pi}_{t-1} \\ & + \kappa\left\{\left(\frac{\alpha+\sigma_l}{1-\alpha} + \frac{\sigma}{1-h}\right)\widehat{y}_t - \frac{\sigma h}{1-h}\widehat{y}_{t-1} - \frac{1+\sigma_l}{1-\alpha}\widehat{a}_t\right\}\end{aligned} \quad \text{(A.24)}$$

Finally, we assume that firms pay out all profits as dividends. This implies that the dividend payment equation can be specified as the difference between the real output and the real total cost.

$$D_t = Y_t - \frac{W_t}{P_t}N_t \quad \text{(A.25)}$$

We substitute for N_t by using Equation (A.17) and the linearized real dividends payment equation is presented as follows:

$$\widehat{d}_t = \left(\frac{1-\phi}{1-\delta}\right)\widehat{y}_t - \left(\frac{\delta}{1-\delta}\right)\widehat{w}_t + \left(\frac{\phi}{1-\delta}\right)\widehat{a}_t \quad \text{(A.26)}$$

In Equation (A.26), $\phi = \frac{\delta}{1-\alpha}$ and $\delta = \frac{W_0 N_0}{P_0 Y_0}$, which is the steady state labour share. By inserting Equation (A.22) into Equation (A.26), the dividend payment equation can be reformulated as presented below:

$$\begin{aligned}\widehat{d}_t = {} & \left(\frac{1-\phi}{1-\delta} - \left(\frac{\delta}{1-\delta}\right)\left(\frac{\sigma_l}{1-\alpha} + \frac{\sigma}{1-h}\right)\right)\widehat{y}_t \\ & + \left(\frac{\delta}{1-\delta}\right)\frac{\sigma h}{1-h}\widehat{y}_{t-1} + \left(\left(\frac{\delta}{1-\delta}\right)\frac{\sigma_l}{1-\alpha}\frac{\phi}{1-\delta}\right)\widehat{a}_t\end{aligned} \quad \text{(A.27)}$$

If we define $\left(\frac{1-\phi}{1-\delta} - \left(\frac{\delta}{1-\delta}\right)\left(\frac{\sigma_l}{1-\alpha} + \frac{\sigma}{1-h}\right)\right) = \eta_a$, $\left(\frac{\delta}{1-\delta}\right)\frac{\sigma h}{1-h} = \eta_b$, $\left(\left(\frac{\delta}{1-\delta}\right)\frac{\sigma_l}{1-\alpha}\frac{\phi}{1-\delta}\right) = \eta_c$, Equation (A.27) can then be rewritten as follows:

$$\widehat{d}_t = \eta_a\widehat{y}_t + \eta_b\widehat{y}_{t-1} + \eta_c\widehat{a}_t \quad \text{(A.28)}$$

To close the model, we follow Challe and Giannitsarou (2014) and use the following monetary policy rule:

$$\widehat{i}_t = \phi_i\widehat{i}_{t-1} + (1-\phi_i)\phi_\pi\widehat{\pi}_t + (1-\phi_i)\phi_y\widehat{y}_t + \widehat{m}_t \quad \text{(A.29)}$$

$$\widehat{R}_t = \widehat{i}_t - E_t\widehat{\pi}_{t+1} \quad \text{(A.30)}$$

In Equation (A.29), ϕ_i is the interest rate smoothing parameter, ϕ_π measures the reaction to inflation, ϕ_y measures the reaction of the central bank to the output gap, and $\hat{m}_t$ represents the monetary policy shock. Equation (A.30) describes the real expected interest rate. The three main exogenous shocks in our model follow the first order autoregressive process. The dynamics of these shocks are described as follows:

$$\widehat{\varepsilon}_t = \rho_p\widehat{\varepsilon}_{t-1} + \mu_t^p \quad \text{(A.31)}$$

$$\widehat{a}_t = \rho_a\widehat{a}_{t-1} + \mu_t^a \quad \text{(A.32)}$$

$$\widehat{m}_t = \rho_m\widehat{m}_{t-1} + \mu_t^m \quad \text{(A.33)}$$

where ρ measures the persistence of each exogenous shock.