The anatomy of standard DSGE models with financial frictions*

Michał Brzoza-Brzezina† Marcin Kolasa‡ Krzysztof Makarski§

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Abstract

In this paper we compare two standard extensions to the New Keynesian model featuring financial frictions. The first model, originating from Kiyotaki and Moore (1997), is based on collateral constraints. The second, developed by Carlstrom and Fuerst (1997) and Bernanke et al. (1999), accentuates the role of external finance premia. Our goal is to compare the workings of the two setups. Towards this end, we tweak the models and calibrate them in a way that allows for both qualitative and quantitative comparisons. Next, we make a thorough analysis of the two frameworks using moment matching, impulse response analysis and business cycle accounting. We describe the transmission mechanisms, document a number of important differences and several counterintuitive features of both models. Overall, while the collateral constraint setup is better at reproducing the main cyclical co-movements between macroeconomic variables, its internal propagation mechanisms are rather weak. In particular, and in contrast to the external finance premium specification, it fails to generate hump-shaped responses to standard shocks and so is inconsistent with empirical evidence on the monetary transmission.

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†National Bank of Poland and Warsaw School of Economics, email: Michal.Brzoza-Brzezina@nbp.pl

‡National Bank of Poland and Warsaw School of Economics, email: Marcin.Kolasa@nbp.pl

§National Bank of Poland and Warsaw School of Economics, email: Krzysztof.Makarski@nbp.pl

1 Introduction

The 2007-2010 financial crisis has shown how deep an impact financial markets can have on macroeconomic behaviour. Shocks originating from the American subprime mortgage market spread worldwide, affecting interbank markets and property markets in developed and developing economies. Financial institutions transmitted these shocks further, restricting lending and raising the cost of borrowing. As a result consumers reduced consumption, enterprises cut investment and the world economy witnessed the first recession since WWII.

One of the important lessons from the crisis was that financial markets matter for macroeconomic developments and should be taken into account when constructing macro models. This resulted in a surge of interest in theoretical frameworks incorporating financial frictions. Models with imperfect financial markets, previously at the margin of professional interest, promptly entered into the mainstream. They were used to answer questions important from the point of view of policymakers, like about (i) the impact of financial shocks on the economy (Gerali et al., 2010, Brzoza-Brzezina and Makarski, 2010), (ii) the optimal monetary policy in the presence of financial frictions (Cúrdia and Woodford, 2008; De Fiore and Tristani, 2009; Carlstrom et al., 2009; Kolasa and Lombardo, 2010), (iii) the effectiveness of alternative monetary policy tools (Lombardo and McAdam, 2010) or (iv) the impact of capital regulations on the economy (Angelini et al., 2010). Finally, it should be added that financial frictions have recently been added to models used for policy purposes at several central banks[1]. This includes the Riksbank's model RAMSES (Christiano et al., 2010) and the European Central Bank's NAWM (Lombardo and McAdam, 2010).

The current literature is mostly based on two alternative approaches developed long before the crisis. One important direction was introduced by the seminal paper of Kiyotaki and Moore (1997). This line of research introduces financial frictions via collateral constraints. Agents are heterogeneous in terms of their rate of time preference, which divides them into lenders and borrowers. The financial sector intermediates between these groups and introduces frictions by requiring that borrowers provide collateral for their loans. Hence, this approach introduces frictions that affect directly the quantity of loans. The original model of Kiyotaki and Moore (1997) has been recently developed by Iacoviello (2005), who introduced housing as collateral. Other recent applications relying on this framework include Calza et al. (2009) who analyse the impact of mortgage market characteristics on monetary transmission. Gerali et al. (2010) and Brzoza-Brzezina and Makarski (2010) use models with collateral constraints and monopolistic competition in the banking sector to examine the impact of financial frictions on monetary transmission and a credit crunch scenario. Iacoviello and Neri (2010) estimate a model with collateral constraints on US data in order to study the role of housing market shocks on the economy.

[1] See Jonsson et al. (2010) for an extensive review.

The second stream of research originates from the seminal paper of Bernanke and Gertler (1989) where financial frictions have been incorporated into a general equilibrium model. This approach has been further developed by Carlstrom and Fuerst (1997) and merged with the New Keynesian framework by Bernanke et al. (1999), becoming the workhorse financial frictions model in the 2000s. In this model frictions arise because monitoring the loan applicant is costly, which drives an endogenous wedge between the lending rate and the risk free rate. This means that financial frictions affect the economy via prices of loans rather than via quantities as in models based on collateral constraints. The external finance premium setup has been extensively used i.a. by Christiano et al. (2003) to analyse the role of financial frictions during the Great Depression and by Christiano et al. (2010) to study business cycle implications of financial frictions. Goodfriend and McCallum (2007) provided an endogenous explanation for steady state differentials between lending and money market rates. In a similar framework, Cúrdia and Woodford (2008) derived optimal monetary policy in the presence of time-varying interest rate spreads in a simple model with heterogeneous households.

While both approaches allow for the the introduction of financial frictions into the workhorse macro model, the propagation mechanisms in the two models may substantially differ. For the development of a successful macro-financial framework it seems crucial to properly understand how price and quantity based frictions work, and to identify the common and the distinct features of the two models. It is trivial to say that collateral constraints and finance premia affect the economy in not exactly the same ways. But what are exactly the differences? How and through which channels do the frictions amplify monetary policy effects? Do they result in intuitive or counterintuitive impulse response functions? What are the main propagation mechanisms?

In this paper we thoroughly compare the consequences of introducing collateral constraints (referred to as CC) and external finance premia (EFP) into a standard medium-sized New Keynesian (NK) DSGE model. Since we are interested in comparing the effect of two different types of financial frictions on the macroeconomy, we keep the CC and EFP versions as similar as possible in all aspects but the financial sector. In particular, while calibrating the models to the data, we keep the non-financial structural parameters the same and set the financial parameters to match the key steady state proportions affected by the presence of financial frictions. Both models are subject to three non-financial shocks (productivity, monetary and government expenditure) and two financial sector shocks. We estimate the former outside of the models. Since the financial sectors differ across the models, so do the financial shocks. Therefore, to ensure comparability, we calibrate them so that both model versions match the autoregressions and the standard deviations of loans and the interest rates spread observed in the data. We investigate the differences between the two modelling approaches using three tools: moment matching, impulse response analysis and business cycle accounting (as proposed by Chari et al. (2007)).

Both models add volatility to the NK framework, bringing it closer to the data. A notable exception is labour, whose volatility is clearly overestimated in the CC model. On the other hand, the EFP variant (like the NK benchmark) implies a negative correlation between employment and output, while the CC model produces a positive comovement between these two variables, as found in the data. Surprisingly, both models with a financial sector fail to capture the positive (even though weak) correlation between loans and GDP. Finally, the CC model generates unreasonably high fluctuations in the price of capital.

Looking at the model-implied inertia of the main macro-categories reveals that the EFP framework has significantly stronger internal propagation mechanisms than the CC setup. This observation is confirmed by the impulse response analysis. Following any standard shock, the speed of return to the steady state is significantly slower in the EFP model and the responses display a hump-shaped pattern. This is in contrast to the CC version, where the strongest response usually occurs on impact. Both models generally dampen the impact of productivity shocks and amplify the impact of monetary policy shocks on investment and output. There are also several interesting qualitative differences and perhaps counterintuitive responses. For instance, in the CC setup there is a short-lived contraction in output following a positive productivity shock.

The business cycle accounting analysis confirms the superior performance of both models with financial frictions over the simple NK framework. The CC variant does particularly well, implying wedges that closely resemble those filtered from the data. The EFP model, even though it improves over the NK benchmark, still yields a negative correlation between output and its component attributed to movements in the labour wedge and overstates the importance of the investment wedge.

The rest of the paper is structured as follows. Section two sketches the baseline NK model, section three presents the two versions of a financial sector. Section four discusses the calibration, section five presents the impulse response analysis and section six the results of business cycle accounting. Section seven concludes.

2 The Benchmark NK Model

Our baseline NK specification is a standard medium-sized closed economy DSGE model with sticky prices and a range of other frictions that have been found crucial for ensuring a reasonable empirical fit (see Christiano et al., 2005; Smets and Wouters, 2003). The model economy is populated by households, producers, fiscal and monetary authorities. Households consume, accumulate capital stock and work. Output is produced in several steps. Fiscal authorities use taxes to fiance exogenously given government expenditure and monetary authorities conduct monetary policy according to the Taylor rule.

2.1 Households

The economy is populated by households of measure one. Each household h chooses consumption c_t^H, labour supply n_t and capital holdings for the next period k_t. The expected lifetime utility of a representative household is as follows

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{\left(c_t^H(h) - \xi c_{t-1}^H\right)^{1-\sigma_c}}{1-\sigma_c} - \frac{n_t(h)^{1+\sigma_n}}{1+\sigma_n} \right] \tag{1}$$

where ξ denotes the degree of external habit formation. The representative household uses labour income $W_t n_t$, capital income $R_{k,t} k_{t-1}$, dividends[2] Π_t and undepreciated capital holdings from the previous period $(1-\delta) k_{t-1}$ to finance its expenditure and lump sum taxes T_t. Each household faces the following budget constraint

$$\begin{aligned} P_t c_t^H(h) + Q_t k_t(h) + R_t^{-1} B_t(h) \leq W_t n_t(h) + (R_{k,t} + Q_t(1-\delta)) k_{t-1}(h) \\ - P_t T_t(h) + \Pi_t(h) + B_{t-1}(h) \end{aligned} \tag{2}$$

where P_t and Q_t denote, respectively, the price of consumption good and capital. As in Chari et al. (2002), we assume that agents have access to state contingent bonds B_t, paying the expected gross rate of return R_t, which allows to insure against idiosyncratic risk.

2.1.1 Labour Supply

We assume that each household has a unique labour type h. Labour services are sold to perfectly competitive aggregators who pool all the labour types into one undifferentiated labour service with the following function

$$n_t = \left(\int_0^1 n_t(h)^{\frac{1}{1+\phi_w}} dh \right)^{1+\phi_w} \tag{3}$$

The problem of the aggregator gives the following demand for labour of type h

$$n_t(h) = \left[\frac{W_t(h)}{W_t} \right]^{\frac{-(1+\phi_w)}{\phi_w}} n_t \tag{4}$$

where

$$W_t = \left(\int_0^1 W_t(h)^{\frac{-1}{\phi_w}} dh \right)^{-\phi_w} \tag{5}$$

is the aggregate wage in the economy.

Households sets their wage rate according the the standard Calvo scheme, i.e. with

[2] Households own all firms in this economy.

probability $(1-\theta_w)$ they receive a signal to reoptimise and then set their wage to maximise their utility subject to the demand for their labour services. With probability θ_w they do not receive the signal and index their wage according to the following rule

$$W_{t+1}(h) = ((1-\zeta_w)\bar{\pi} + \zeta_w \pi_{t-1}) W_t(h) \tag{6}$$

where $\bar{\pi}$ is the steady state inflation rate and $\zeta_w \in [0,1]$.

2.2 Producers

There are several stages of production in the economy. Intermediate goods firms produce differentiated goods and sell them to aggregators. Aggregators combine differentiated goods into a homogeneous final good. The final good can be used for consumption or sold to capital goods producers.

2.2.1 Capital Good Producers

Capital good producers act in a perfectly competitive environment. In each period a representative capital good producer buys i_t of final goods and old undepreciated capital $(1-\delta)k_{t-1}$. Next she transforms old undepreciated capital one-to-one into new capital, while the transformation of the final goods is subject to an adjustment cost $S(i_t/i_{t-1})$. We adopt the specification of Christiano et al. (2005) and assume that in the deterministic steady state there are no capital adjustment costs ($S(1) = S'(1) = 0$), and the function is concave in its neighbourhood ($S''(1) = \kappa > 0$). Thus, the technology to produce new capital is given by

$$k_t = (1-\delta)k_{t-1} + \left(1 - S\left(\frac{i_t}{i_{t-1}}\right)\right) i_t \tag{7}$$

The new capital is then sold in a perfectly competitive market to households and can be used in the next period production process. The real price of capital is denoted as $q_t = Q_t/P_t$.

2.2.2 Final Good Producers

Final good producers play the role of aggregators. They buy differentiated products from intermediate goods producers $y(j)$ and aggregate them into a single final good, which they sell in a perfectly competitive market. The final good is produced according to the following technology

$$y_t = \left(\int_0^1 y_t(j)^{\frac{1}{1+\phi}} dj\right)^{1+\phi} \tag{8}$$

The problem of the aggregator gives the following demands for differentiated goods

$$y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{\frac{-(1+\phi)}{\phi}} y_t \tag{9}$$

where

$$P_t = \left[\int P_t(j)^{\frac{-1}{\phi}} dj\right]^{-\phi} \tag{10}$$

is the price of the consumption good.

2.2.3 Intermediate Goods Producers

There is a continuum of intermediate goods producers of measure one denoted by j. They rent capital and labour from the households and use the following production technology

$$y_t(j) = A_t k_t(j)^{\alpha} n_t(j)^{1-\alpha} \tag{11}$$

where A_t is the total factor productivity, the log of which follows an exogenous $AR(1)$ process.[3]

Intermediate goods firms act in a monopolistically competitive environment and set their prices according to the standard Calvo scheme. In each period each producer receives with probability $(1-\theta)$ a signal to reoptimise and then sets her price to maximise the expected profits, subject to demand schedules given by (9). Those that are not allowed to reoptimise index their prices according to the following rule

$$P_{t+1}(j) = P_t(j)\left((1-\zeta)\bar{\pi} + \zeta\pi_{t-1}\right) \tag{12}$$

where $\zeta \in [0,1]$.

2.3 Government

The government uses lump sum taxes to finance government expenditure. For simplicity, we assume that the government budget is balanced each period so that

$$g_t = T_t. \tag{13}$$

where g_t denotes government expenditure, driven by a simple AR(1) process

$$\ln g_t = (1-\rho_g)\ln \mu_g + \rho_g \ln g_{t-1} + \varepsilon_{g,t}. \tag{14}$$

[3]The autoregressive coefficient is ρ_A and the standard deviation is σ_A.

with i.i.d. normal innovations (the standard deviation is σ_g), $\rho_g \in (0,1)$ and μ_g denoting the steady state level of government purchases.

2.4 Central Bank

As it is common in the New Keynesian literature, we assume that monetary policy is conducted according to a Taylor rule that targets deviations of inflation and GDP from the deterministic steady state, allowing additionally for interest rate smoothing

$$R_t = \left(\frac{R_{t-1}}{\bar{R}}\right)^{\gamma_R} \left(\left(\frac{\pi_t}{\bar{\pi}}\right)^{\gamma_\pi} \left(\frac{y_t}{\bar{y}}\right)^{\gamma_y}\right)^{1-\gamma_R} e^{\varphi_t} \tag{15}$$

where y denotes GDP, $\pi_t = \frac{P_t}{P_{t-1}}$, and φ_t are i.i.d. normal innovations (the standard deviation is σ_R).

2.5 Market Clearing

To close the model, we need the market clearing condition for the final goods market

$$c_t + i_t + g_t = y_t \tag{16}$$

where $c_t = c_t^H$ (only households consume). Finally, the factor markets need to clear as well

$$k_{t-1} = \int_0^1 k_t(j)\, dj \tag{17}$$

$$n_t = \int_0^1 n_t(j)\, dj \tag{18}$$

3 Financial frictions

In the NK model presented above, financial markets work perfectly. In particular, agents can make deposits and take loans in any quantity at the risk free rate R_t, fully controlled by the central bank. This will no longer be the case in the extensions discussed in this section.

Implementing any credit imperfections requires distinguishing between borrowers and lenders. As in both EFP and CC versions financial frictions emerge at the level of capital management, its ownership needs to be separated from the households. Therefore, one introduces a new type of agents, named entrepreneurs, who specialise in capital management.[4] Entrepreneurs finance their operations, i.e. renting capital services to firms, by taking loans

[4]This means in particular that terms related to capital management drop out from households' budget constraint (2).

from the banking sector, which refinances them by accepting deposits from the households. The financial intermediation between households and entrepreneurs is subject to frictions, which result in interest rate spreads or quantity constraints.

3.1 External finance premium version (EFP)

In the EFP version, financial frictions arise because management of capital is risky. Individual entrepreneurs are subject to idiosyncratic shocks, which are observed by them for free, while the lenders can learn about the shocks' realisations only after paying monitoring costs. This costly state verification problem (Townsend, 1979) results in a financial contract featuring an endogenous premium between the lending rate and the risk-free rate, which depends on borrowers leverage. Since the banking sector is perfectly competitive and entrepreneurs are risk neutral, banks pay interest on household deposits equal to the risk-free rate and break even every period.

3.1.1 Entrepreneurs

There is a continuum of risk-neutral entrepreneurs, indexed by ι. At the end of period t, each entrepreneur purchases installed capital $k_t(\iota)$ from capital producers, partly using her own financial wealth $V_t(\iota)$ and financing the remainder by a bank loan $L_t(\iota)$

$$L_t(\iota) = Q_t k_t(\iota) - V_t(\iota) \geq 0 \tag{19}$$

After the purchase, each entrepreneur experiences an idiosyncratic productivity shock, which converts her capital to $a_E(\iota)k_t(\iota)$, where a_E is a random variable, distributed independently over time and across entrepreneurs, with a cumulative density function $F(\iota)$ and a unit mean. Following Christiano et al. (2003), we assume that this distribution is log normal, with a time-varying standard deviation of $\log a_E$ equal to $\varepsilon_{E,t}\sigma_{a_E}$ [5] , known to entrepreneurs before their capital decisions.

Next, each entrepreneur rents out capital services, treating the rental rate $R_{k,t+1}$ as given. Since the mean of an idiosyncratic shock is equal to one, the average rate of return on capital earned by entrepreneurs can be written as

$$R_{E,t+1} = \frac{R_{k,t+1} + (1-\tau)Q_{t+1}}{Q_t} \tag{20}$$

and the rate of return earned by an individual entrepreneur is $a_E(\iota)R_{E,t+1}$.

Since lenders can observe the return earned by borrowers only at a cost, the optimal contract between these two parties specifies the size of the loan $L_t(\iota)$ and the gross non-default interest rate $R_{L,t+1}(\iota)$. The solvency criterion can also be defined in terms of a cutoff

[5] The autoregressive coefficient is ρ_E and the standard deviation is σ_E.

value of idiosyncratic productivity, denoted as $\tilde{a}_{E,t+1}(\iota)$, such that the entrepreneur has just enough resources to repay the loan[6]

$$\tilde{a}_{E,t+1} R_{E,t+1} Q_t k_t(\iota) = R_{L,t+1} L_t(\iota) \tag{21}$$

Entrepreneurs with a_E below the threshold level go bankrupt. Their all resources are taken over by the banks, after they pay proportional monitoring costs μ.

3.1.2 Banks

Banks finance their loans by issuing time deposits to households at the risk-free interest rate R_t. The banking sector is assumed to be perfectly competitive and owned by risk-averse households. This, together with risk-neutrality of entrepreneurs implies a financial contract insulating the lender from any aggregate risk.[7] Hence, interest paid on a bank loan by entrepreneurs is state contingent and guarantees that banks break even in every period. The aggregate zero profit condition for the banking sector can be written as

$$(1 - F_{1,t+1}) R_{L,t+1} L_t + (1 - \mu) F_{2,t+1} R_{E,t+1} Q_t k_t = R_t L_t \tag{22}$$

or equivalently (using (21))

$$R_{E,t+1} Q_t k_t \left[\tilde{a}_{E,t+1}(1 - F_{1,t+1}) + (1 - \mu) F_{2,t+1}\right] = R_t L_t \tag{23}$$

where

$$F_{1,t} = \int_0^{\tilde{a}_{E,t}} dF(a_E) \tag{24}$$

$$F_{2,t} = \int_0^{\tilde{a}_{E,t}} a_E dF(a_E) \tag{25}$$

3.1.3 Optimal contract

The equilibrium debt contract maximises welfare of each individual entrepreneur. It is defined in terms of expected end-of-contract net worth relative to the risk-free alternative, which is holding a domestic bond

$$E_t \left\{ \frac{\int_{\tilde{a}_{E,t}}^{\infty} \left(R_{E,t+1} Q_t k_t(\iota) a_E(\iota) - R_{L,t+1} L_t(\iota)\right) dF(a_E(\iota))}{R_t V_t(\iota)} \right\} \tag{26}$$

[6] In order to save on notation, in what follows we use the result established later on, according to which the cutoff productivity $\tilde{a}_E(z_E)$ and the non-default interest paid on a bank loan $R_{B,t+1}(z_E)$ is identical across entrepreneurs.

[7] Given the infinite number of entrepreneurs, the risk arising from idiosyncratic shocks is fully diversifiable.

The first-order condition to this optimisation problem can be written as

$$E_t \left\{ \begin{array}{c} \frac{R_{E,t+1}}{R_t} \left[1 - \tilde{a}_{E,t+1}(1 - F_{1,t+1}) - F_{2,t+1}\right] + \\ + \frac{1 - F_{1,t+1}}{1 - F_{1,t+1} - \mu \tilde{a}_{E,t+1} F'_{1,t+1}} \left(\frac{R_{E,t+1}}{R_t} \left[\tilde{a}_{E,t+1}(1 - F_{1,t+1}) + (1 - \mu) F_{2,t+1}\right] - 1 \right) \end{array} \right\} = 0 \quad (27)$$

As can be seen from (27), the ex ante external financing premium arises because of monitoring costs. If μ is set to zero, the expected rate of return on capital is equal to the risk-free interest rate and so the financial markets work without frictions.

Equation (27), together with the bank zero profit constraint (23), defines the optimal debt contract in terms of the cutoff value of the idiosyncratic shock $\tilde{a}_{E,t+1}$ and the leverage ratio ϱ_t, defined as:

$$\varrho_t = \frac{Q_t k_t}{V_t} \quad (28)$$

These two contract parameters are identical across entrepreneurs. Similarly, the rate of interest paid to the bank is the same for each non-defaulting entrepreneur:

$$R_{L,t+1} = \frac{\tilde{a}_{E,t+1} R_{E,t+1} \varrho_t}{\varrho_t - 1} \quad (29)$$

We will refer to the difference between this rate and the risk-free rate R_t as the credit spread. It is easy to show that both the external finance premium and the credit spread depend positively on the leverage.

3.1.4 Net worth evolution and resource constraint

Proceeds from selling capital, net of interest paid to the bank, constitute end of period net worth. To capture the phenomenon of ongoing entries and exits of firms and to ensure that entrepreneurs do not accumulate enough wealth to become fully self-financing, it is assumed that each period a randomly selected and time-varying fraction $1 - \varepsilon_{\nu,t}\upsilon$[8] of them go out of business, in which case all their financial wealth is rebated to the households. At the same time, an equal number of new entrepreneurs enters, so that the total number of entrepreneurs is constant. Those who survive and enter receive a transfer T_E from the households. This ensures that both entrants and surviving bankrupt entrepreneurs have at least a small but positive amount of wealth, without which they would not be able to buy any capital.

Aggregating across all entrepreneurs and using (23) yields the following law of motion for net worth in the economy:

$$V_t = \varepsilon_{\nu,t}\upsilon \left[R_{E,t} Q_{t-1} k_{t-1} - \left(R_{t-1} + \frac{\mu F_{2,t} R_{E,t} Q_{t-1} k_{t-1}}{L_{t-1}} \right) L_{t-1} \right] + T_E \quad (30)$$

[8]The autoregressive coefficient is ρ_v and the standard deviation is σ_v.

The term in the square brackets represents the total revenue from renting and selling capital net of interest paid on bank loans, averaged over both bankrupt and non-bankrupt entrepreneurs.

Finally, as monitoring costs are real, the aggregate resource constraint from the NK model (16) needs to be modified so that it becomes

$$c_t + i_t + g_t + \mu F_{2,t} R_{E,t} Q_{t-1} k_{t-1} = y_t \tag{31}$$

However, to ensure comparability across the models, we will use y_t net of monitoring costs as our proxy for output in the exercises presented in the next sections.

3.2 Collateral constraint version (CC)

The key financial friction in the CC version is introduced by assuming that borrowers need collateral to take a loan. The restrictiveness of this constraint is perturbed stochastically in the form of a shock to the required loan-to-value (LTV) ratio. Additionally, to ensure comparability with the EFP version, we assume that the interest rates on loans differ from the risk free rate. The difference is due to technological reasons and is subject to exogenous shocks.

Similarly as in the case of the goods producers, banking activity is divided into several steps. First, banks collect deposits from the households and use them to offer differentiated loans to financial intermediaries. Financial intermediaries aggregate all differentiated loans into a homogeneous loan that is offered to entrepreneurs.

3.2.1 Entrepreneurs

There is a measure γ_E of entrepreneurs in the model, indexed by ι. They draw utility only from their consumption c_t^E

$$E_0 \sum_{t=0}^{\infty} (\beta_E)^t \left(\frac{\left(c_t^E(\iota) - \xi c_{t-1}^E\right)^{1-\sigma_c}}{1-\sigma_c} \right) \tag{32}$$

Entrepreneurs cover their consumption and capital expenditures with revenues from renting capital services to wholesale goods producers, financing the remainder by bank loans L_t, on which the interest to pay is $R_{L,t}$.

$$P_t c_t^E(\iota) + Q_t k_t(\iota) + R_{L,t-1} L_{t-1}(\iota) = (R_{k,t} + Q_t(1-\delta)) k_{t-1}(\iota) + L_t(\iota) \tag{33}$$

Loans taken by the entrepreneurs are subject to the following collateral constraint

$$R_{L,t} L_t(\iota) \leq m_t E_t \left[Q_{t+1} (1-\delta_k) k_t(\iota) \right] \tag{34}$$

where m_t is firm's loan-to-value ratio, the log of which follows an $AR(1)$ process with i.i.d. normal innovations[9].

Since both entrepreneurs and households consume, the aggregate consumption is a sum of their consumption expenditures

$$c_t = c_t^H + \gamma_E c_t^E \tag{35}$$

3.2.2 Financial Intermediaries

Financial intermediaries take differentiated loans from lending banks $L_t(i)$ at the interest rate $R_{L,t}$ and aggregate them into one undifferentiated loan L_t that is offered to entrepreneurs at the rate $R_{L,t}$. The technology for aggregation is

$$L_t = \left[\int_0^1 L_t(i)^{\frac{1}{1+\mu_L}} \, di \right]^{1+\mu_L} \tag{36}$$

Financial intermediaries operate in a competitive market, thus they take the interest rates as given and maximise their profits

$$R_{L,t} L_t - \int_0^1 R_{L,t}(i) \, L_t(i) \, di \tag{37}$$

subject to (36).

Solving the problems above we get the demand for the lending banks' loans

$$L_t(i) \quad = \quad \left(\frac{R_{L,t}(i)}{R_{L,t}} \right)^{-\frac{(1+\mu_L)}{\mu_L}} L_t, \tag{38}$$

and from the zero profit condition we get the interest rate on loans to entrepreneurs

$$R_{L,t} \quad = \quad \left(\int_0^1 R_{L,t}(i)^{-\frac{1}{\mu_L}} \, di \right)^{-\mu_L} \tag{39}$$

3.2.3 Banks

The bank i offers deposits $D_t(i)$ to the households at the risk-free rate R_t, and uses them for lending to financial intermediaries $L_t(i)$ at the interest rate $R_{L,t}(i)$. In order to introduce time varying spreads, we assume that for each unit of deposits, $z_{L,t}$ units of loans can be made, where $\ln z_{L,t}$ follows an $AR(1)$ process with mean one and i.i.d. normal innovations[10]

$$L_t(i) = z_{L,t} D_t(i) \tag{40}$$

[9] The autoregressive coefficient is ρ_m and the standard deviation is σ_m.

[10] The autoregressive coefficient is ρ_{z_L} and the standard deviation is σ_{z_L}.

The bank operates in a monopolistically competitive market, so it sets its interest rate to maximise its profits

$$R_{L,t}(i)\,L_t(i) - R_t D_t(i) \tag{41}$$

subject to the deposits demand (38) and (40).

4 Calibration

The main goal of calibration is to achieve the highest possible comparability between the EFP and CC specifications. This task is not trivial since both versions have different forms of financial frictions and thus we cannot assume equal parameters and stochastic processes across the models. Nevertheless, we are able to succeed by applying a very precise calibration procedure, whose details are presented in Tables 1 to 3.

We start with the structural parameters unrelated to the financial sector and so common across the NK, EFP and CC versions. We take their values directly from the literature, relying mainly on Smets and Wouters (2007), or set them to match the key steady state proportions of the US data.

In each of our extensions to the NK setup, the financial sector is governed by four parameters, which pin down four steady state proportions: investment share in GDP, external finance premium (in EFP) / spread (in CC)[11], capital to debt ratio and entrepreneurs' share in total consumption[12]. The first three have their natural empirical counterparts, which we match exactly. Since it is not clear what the share of entrepreneurs should be, we do not target any specific value for this ratio but rather let it adjust so that the primitive financial sector parameters implied by our calibration strategy are broadly consistent with those used in the previous literature.

We apply a similar procedure to calibration of stochastic shocks. We first calibrate the shocks that are common for the NK, EFP and CC models.The parameters of the technology shock are taken from Cooley and Prescott (1995) and those describing the monetary shock come from Smets and Wouters (2007). For the government expenditure shock, we set the autoregression coefficient at 0.95, which is standard in the literature, and we calibrate the standard deviation to match it with the data on real government spending. Next, we calibrate the financial shocks in the EFP and the CC models. In the former, we have net worth and entrepreneur riskiness shocks, while in the latter we have LTV and spread shocks. These shocks are different but they govern the behaviour of two financial variables appearing in both models: spreads and loans to firms. While calibrating these shocks, we simulate both models

[11]Following Bernanke et al. (1999), it is standard in the EFP literature to calibrate the steady state external finance premium to match the average spread on loans to firms.

[12]In the EFP version, this share is defined as the ratio of transfers from exiting entrepreneurs, net of transfers to them (T_E), to total income of the households.

with the three standard shocks (already calibrated) and the two financial sector shocks. We set the parameters of the latter to match autocorrelations and standard deviations of spreads and loans to firms observed in the data. This procedure anchors the magnitude and inertia of financial sector shocks, thus enabling us to calibrate models with different financial sector structures in a coherent way.

To see what our calibration strategy implies for the role played by different shocks in each model version, in Tables 4 to 6 we present the results of the variance decomposition. In the NK variant, virtually all volatility of the main macroaggregates can be attributed to productivity shocks. This is no longer the case once we add financial frictions. It is worth noting that in both versions of our models with imperfect financial markets, financial shocks are very important, which is consistent with recent findings of Jermann and Quadrini (2009). The overall picture is very similar for the EFP and CC models, with the highest share of of variance driven by productivity and net worth/LTV shocks. The notable differences are relatively low importance of productivity shocks for investment in the EFP version and a smaller contribution of net worth shocks for labour in the EFP model than that of LTV shocks in the CC version.

Given our method of calibration, we can compare the behaviour of the models along the dimensions that were not used in the calibration process. Table 7 documents several important differences in the standard deviations. First, labour in the CC model is almost twice as volatile as in the EFP or NK model, which are broadly in line with the data. Second, the volatility of the real price of capital is an order of magnitude larger in the CC model than in the EFP model, which in turn implies two times larger volatility than the NK model. There are also several less striking differences between the models. All of them generate standard deviation of output close to that observed in the data, with slightly higher volatility in the CC model and slightly smaller in the EFP and NK specifications. Both financial frictions models clearly improve over the NK variant in terms of matching consumption volatility. A similar pattern is observed for investment. Overall, one can conclude that both types of financial frictions add volatility to the baseline NK model, bringing it closer to the data.

There are more differences between the models when one looks at autocorrelations. The most notable one is very high autocorrelation of GDP, labour, consumption and investment in the EFP and the NK models (in most cases higher than in the data) and substantially lower autocorrelation of the same variables in the CC model (usually lower than in the data). The real price of capital is moderately autocorrelated in the NK and EFP models, while it is close to white noise in the CC model.

There are also important differences in correlations of the main macro variables with GDP between the models. It is well known that a standard NK model with a dominant role of productivity shocks implies countercyclicality of labour, which is clearly in contrast with the data. Both versions of financial frictions improve upon it in this respect, but only the

CC variant gets the sign right. The EFP model clearly underestimates the procyclicality of consumption, while the CC and NK overestimate that of investment. Unlike in the data, both inflation and interest rates are highly negatively correlated in all three models. It can be noted, however, that the CC specification comes closest to the observed value. Interestingly, introducing neither of the two versions of financial frictions results in procyclicality of loans. The correlation of spreads with GDP in the EFP model is slightly more negative than in the data, while in the CC variant it is somewhat too weak. In all three specifications, the correlation of the real price of capital with GDP is positive, with the CC version reporting the highest and the EFP model the lowest values.

To sum up, adding financial market imperfections improves the data fit of the NK model. Nevertheless, there are important differences between the two ways of introducing the frictions. First, labour is more volatile and procyclical in the CC model, while it is more stable and countercyclical in the EFP model. Second, investment fluctuates more and is less correlated with GDP in the EFP model than in the CC model. Third, the price of capital is several times more volatile in the CC model than in the EFP model. Importantly, the presence of a financial sector increases the volatility of the main macrovariables (especially investment) and lowers or even reverts the negative correlation of labour with GDP.

5 Impulse Response Analysis

A natural way to explain the results reported in the previous section is to compare the impulse responses of the analysed models to various shocks. Such an analysis highlights and helps to understand the key differences in the propagation mechanisms embedded in various setups. We begin with the standard macroeconomic shocks (productivity and monetary policy), common to all model versions. We next move to shocks specific to the financial frictions literature (net worth, LTV, riskiness and spreads). As we have already mentioned, financial shocks differ in our two model variants by construction and so are not fully comparable. However, there is some conceptual analogy between the net worth shock in the EFP model and the LTV shock from the CC version. Similarly, a natural counterpart of the riskiness shock (EFP) is the spread shock (CC). Therefore, we present the impulse response analysis for the financial shocks by grouping them into these two pairs. In all Figures 1 to 4, the impulse response functions for the EFP model are denoted with the solid line, for the CC model with the dashed line and for the standard NK model with the dotted line. Moreover, since there are no financial frictions in the NK model, we only present its impulse response functions to a productivity and a monetary shock.

5.1 Productivity shock

Figure 1 shows the reactions to a positive productivity shock. As in the standard NK model, the shock lowers the marginal cost and drives inflation down. This process has a non-standard impact on the CC model. Lower inflation raises the real value of debt and forces the constrained agents to decumulate capital and reduce consumption. Demand for capital falls, bringing down investment and the real price of capital. This in turn results in a further tightening of the collateral constraint, further decreasing investment, consumption and output. As a result, the initial reactions of the real variables are non-standard, only in later periods the usual positive effects of higher productivity prevail.

In the EFP model, lower inflation also raises the real value of loans, thus increasing leverage. This results in higher spreads between the lending rate and the risk free rate. However, entrepreneurs do not face direct collateral constraints, so higher spreads make them cut capital spending only marginally on impact and the effect of higher productivity prevails already in the next period. Still, as tighter lending standards do not die out quickly, the expansion in investment is significantly weaker than in the standard NK model and in the medium run it also falls short of that in the CC version. The flip side of an increase in the real value of loans is an increase in the real value of households' deposits. This wealth effect boosts their consumption and ensures a positive response of output already from the beginning.

Overall, since debt in both models with financial frictions is nominal, a decrease in inflation resulting from a positive productivity shocks leads to a debt deflation effect, which dampens the response of investment and output compared to the NK model. The dampening impact of the CC setup is mostly pronounced in the short run, while that of the EFP is spread over time.

5.2 Monetary policy shock

Figure 2 presents the impulse responses to a monetary policy shock. Following the shock, nominal and real interest rates rise and, as in the standard NK model, aggregate demand declines. Lower demand for capital makes its price go down, which has an amplifying effect in models with financial frictions. In the CC version, lower value of collateral forces the constrained agents to save on consumption and investment. This drives the price of capital further down, tightening the lending constraint even more. Since inflation falls, the demand side is additionally weakened by the debt deflation channel. As a result, investment, consumption and output sharply decline on impact, but then recover relatively quickly following the rise in the price of capital.

In the EFP model, the fall in the price of capital subtracts from entrepreneurs' net worth, which together with a rising real value of their debt translates into a higher spread between the lending and the risk free rate. This mechanism amplifies the initial impact of monetary tightening on investment, though by substantially less than the direct collateral effect in the CC model. The positive effect of unexpected deflation on households' wealth further increases the difference between the output response across the two alternative approaches. On the other hand, as entrepreneurs' balance sheets (and so lending conditions) improve only gradually, the speed of reversion to the steady state is much lower in the EFP variant.

5.3 Net worth and loan-to-value ratio shock

In Figure 3 we compare the impact of a shock to net worth (implemented as an increase in the survival rate of entrepreneurs) on the EFP model to the impact of an LTV shock on the CC model. The shock definitions are not fully equivalent. Nevertheless, there are some similarities between them. First of all, both shocks have an expansionary impact on the economy. A higher LTV ratio allows entrepreneurs to demand more loans, increase consumption and investment. Higher net worth increases entrepreneurs' stake in financing capital expenditures and so allows them to borrow at a lower premium over the risk free rate. It is also worth noting that the two shocks are very important sources of fluctuations in both models, accounting for more than half of output variance.

The transmission of an LTV shock in the CC model is fairly intuitive. Entrepreneurs increase borrowing and use the proceeds to invest and consume more, which raises output. Higher demand for capital sharply increases its price, relaxing the collateral constraint further. The boom translates into an increase in inflation. The reactions are very fast but short-lived, with output and private demand components peaking in the first quarter, but then turning negative already in the second year.

The story behind the reaction of the EFP model to a net worth shock differs in several vital respects. As in the case of an LTV shock, the responses of investment and output are positive, but exhibit a hump-shaped pattern, gaining momentum and dying out very slowly. The second striking difference across the models concerns the reactions of consumption and debt. Since a positive net worth shock is defined in the EFP version as a decrease in the number of exiting entrepreneurs, it implies lower wealth transfers to households. As a result, households cut consumption and savings, the latter bringing about a fall in debt. Finally, in contrast to an increase in the LTV ratio, a boost to net worth leads to a fall in inflation, indicating that the two shocks imply a different balance of supply and demand effects.

5.4 Riskiness and spread shock

While the net worth and LTV shocks affected primarily the available quantity of loans, the entrepreneur riskiness (EFP) and spread (CC) shocks directly affect their cost. As can be seen from the response of spreads in both models (see Figure 4), the degree of comparability between these two shocks is very high. Therefore, even though they contribute relatively less to the variance of non-financial variables, their inspection is useful in highlighting the differences between the two financial sector variants considered in this paper.

In the CC model, higher spreads tighten the collateral constraint, affecting negatively loans, consumption and investment. As a result, output and labour input fall as well. As the demand for capital decreases, its price goes down. The story in the EFP model is similar. Higher riskiness of projects run by entrepreneurs makes banks demand a higher premium on the loans to entrepreneurs, which discourages the latter from investing. As a result, loans, output and the price of capital decrease. In both models, shocks affecting spreads act like cost push shocks, driving output and inflation in opposite directions.

Again, the main difference between the two alternative specifications concerns how the responses are spread over time. In the CC variant, all real variables are most strongly affected on impact. In the EFP version, output, consumption, investment and debt display an inverted hump-shaped pattern and there is even a short-lived increase in labour input. The latter, somewhat counterintuitive effect results from an increase in the bankruptcy rate, which means that more resources are needed to cover monitoring costs.[13]

5.5 Summary

Several more general observations can be drawn from the analysis of impulse response functions presented above. First, in all cases the reaction of the CC model is much faster than that of the EFP model. In particular, the CC model usually generates reaction functions with the deepest impact occurring in the first quarter of the shock. This seems inconsistent with VAR evidence on monetary transmission, where the reactions are usually hump-shaped, more like in the EFP model. Second, in the CC model all shocks exercise a very strong influence on the price of capital, driving it down or up by as much as 10-20% after a standard shock. This seems inconsistent with empirical estimates of the price of capital behaviour. Finally, some of the impulse response functions are counterintuitive in sign. One notable example is the initial decline of output after a productivity shock in the CC model. Another is related to the strong and very persistent deflationary effect of a positive net worth shock in the EFP model.

6 Business Cycle Accounting

To shed more light on the differences between the EFP and CC setups, we filter the artificial data generated from these two versions of through the business cycle accounting procedure developed by Chari et al. (2007). In a nutshell, this approach considers a standard real

[13] For the same reason, a similar pattern can be observed for output including monitoring costs.

business cycle model with time-varying wedges that resemble productivity, labour and investment taxes, and government spending. The wedges are assumed to follow a first-order vector autoregressive process. The original idea of the Chari et al. (2007) paper was to take this prototype economy to the observed data and examine the role of each wedge in accounting for fluctuations in the main macro variables. The outcomes could then be used to judge which frictions are quantitatively important for business cycle fluctuations. We do the same exercise on simulated data, with the purpose to highlight the main differences between the propagation mechanisms embedded in our alternative models and evaluate consistency of these mechanisms with actual data.

6.1 Setup

We design our prototype economy in a similar way as in Chari et al. (2007). The only difference is the capital adjustment cost, which we define as a function of a change in investment, consistently with our baseline model structure presented in section 2.

The households' problem is to maximise their discounted lifetime utility

$$E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{c_t^{1-\sigma_c}}{1-\sigma_c} - \frac{n_t^{1+\sigma_n}}{1+\sigma_n} \right) \tag{42}$$

subject to budget constraint

$$c_t + (1+\tau_{i,t})i_t = r_{k,t}k_{t-1} + (1-\tau_{l,t})w_t n_t - T_t \tag{43}$$

and capital accumulation

$$k_t = (1-\delta)k_{t-1} + \left(1 - S\left(\frac{i_t}{i_{t-1}}\right)\right) i_t \tag{44}$$

Firms are perfectly competitive and maximise their profits

$$y_t - r_{k,t}k_{t-1} - w_t n_t \tag{45}$$

subject to production function

$$y_t = A_t k_{t-1}^{\alpha} n_t^{1-\alpha} \tag{46}$$

The aggregate resource constraint is

$$y_t = c_t + i_t + g_t \tag{47}$$

All variables are defined as in our baseline setup, except that factor prices are now expressed in real terms and so denoted by lower case letters. The four wedges are A_t, $\tau_{l,t}$,

$\tau_{i,t}$ and g_t. We will refer to them as efficiency, labour, investment and government wedges, respectively.

We calibrate the structural parameters of the prototype economy as in section 4 and estimate the stochastic process for wedges using 25000 observations simulated from each model, as well as actual data for the US economy, covering the period 1970q1-2008q4. As in the original business cycle accounting procedure, the observable variables are output, labour, investment and government spending. The estimation method is maximum likelihood.

6.2 Results

To see the role of each wedge in each of our datasets, we run the estimated business cycle accounting models with all wedges and with each wedge separately. The results of these exercises are presented in Table 8.

In the first three panels we present, respectively, standard deviations, autocorrelations, and correlations with output for the components of output implied by each single wedge. Starting from the standard deviations, one can see that all our models generate similar and excessive volatility of the efficiency component of output. Important differences concern the labour and investment wedges. In the NK model, their output components fluctuate substantially less than in the data. The EFP version overemphasises the contribution of the investment wedge and underestimates that of the labour wedge, while the opposite picture emerges for the CC variant. As in the data, the role of government spending wedge is marginal in all three models.

As regards autocorrelations, the differences between the NK and EFP models are very small. Both feature too much inertia of the efficiency component and too little inertia of that resulting from movements in the labour wedge. The latter shortcoming is even more pronounced in the CC variant, which additionally underestimates the autocorrelation related to the investment wedge.

The analysed models have substantially different implications for the correlations of individual wedge components with output. Productivity shocks account for virtually all output fluctuations in the NK model, so it should come as no surprise that the efficiency component is much more correlated with output in this simple version than in the case for our two model variants with financial frictions. In this respect, the data fit of the NK and EFP models is comparable, while that of the CC is somewhat worse.

Moving to the labour wedge, its output component is countercyclical in the NK and EFP variants, which is clearly at odds with the data. In this respect, the CC variant performs remarkably well. These differences across the models can be traced back to their responses to technology shocks, discussed in section 5.1. While in all three variants a positive technology shock leads to a fall in labour, its short-run impact on output is positive in the NK and EFP models, but negative in the CC version. Since the standard real business cycle model implies a strong and positive correlation between these two variables, their negative comovement in the NK and EFP setups translates into a negative correlation between the labour and efficiency wedges. Similarly, the initial drop in output following a positive productivity shock in the CC variant weakens the procyclicality of the efficiency component of output.

Finally, both variants with the financial sector imply procyclicality of the investment wedge component, slightly overestimating it (especially the EFP version) relative to the data. In contrast, this output component is strongly countercyclical in the NK setup. This comes out from the fact that, in the absence of financial frictions, movements in the investment wedge result mainly from price stickiness. As demonstrated by Sustek (2010), this friction manifests itself as equal movements in the labour and investment wedges in the prototype economy, both of which respond negatively to a positive productivity shock, the main driving force in the NK variant.

We complement our moment analysis with output variance decomposition by wedges. Since the wedges, and hence their output components, are correlated with each other, we use the standard approach in the literature (see e.g. Caselli, 2005) and split the covariances equally within any of the pairs of variables. More specifically, we have $y = \sum_i y_i$, where y_i denotes output component of wedge i. The variance of y is equal to

$$\mathrm{Var}y = \sum_i \mathrm{Var}y_i + \sum_i \sum_{j \neq i} \mathrm{Cov}(y_i, y_j) \tag{48}$$

We calculate the contribution of y_i to the variance of y as

$$\mathrm{Var}(y|y_i) = \frac{\mathrm{Var}y_i + \sum_{j \neq i} \mathrm{Cov}(y_i, y_j)}{\mathrm{Var}y} \tag{49}$$

The results of the variance decomposition analysis support the findings discussed above. Using this metric, both models with financial frictions clearly outperform the simple NK setup. Among the two, the mix of wedges implied by the CC model resembles that from the data much more than the EFP version. In particular, the latter overemphasises the importance of the investment wedge and misses the right contribution of efficiency and labour wedges.

7 Conclusions

In this paper we make a thorough comparison between two standard ways of introducing financial frictions into a standard New Keynesian model. To make this task possible, we tweak the models to make them comparable in all respects but the financial sector setup. We achieve this goal by using a careful calibration strategy. We next analyse the differences between the two alternative approaches with the following tools: moment matching, impulse response analysis and business cycle accounting.

Both types of frictions clearly improve upon the standard NK framework. They bring the moments of most of the main macrovariables closer to the data. In particular, the CC setup succeeds in turning the negative correlation between output and labour, characteristic for the standard NK model, to a positive value. This feature is crucial for the remarkably good performance of this variant, evaluated through the lens of the business cycle accounting framework.

The impulse response analysis reveals important differences in the propagation mechanisms between the CC and EFP variants. The former usually generates reaction functions with the deepest impact occurring in the first quarter of the shock, while those obtained from the latter are usually hump-shaped. Further, in the CC model all shocks exercise much stronger influence on the price of capital. It is worth noting that the impulse response functions obtained from the models with financial frictions are not always intuitive, like the initial decline of output after a positive productivity shock in the CC model.

Overall, the two alternative ways of incorporating financial frictions into the canonical New Keynesian framework clearly improve it in several areas. Nevertheless, they also show a number of features that seem at odds with intuition or empirical evidence. We believe that this paper will support the process of identifying macro-financial linkages that match the data and economic intuition, which will benefit both academic and policy oriented research.

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Tables and Figures

Table 1: Structural parameters

Parameter	Values	Description
Households		
β	0.995	discount rate
σ_c	2.0	inverse of intertemporal elasticity of substitution
σ_n	2.0	inverse of Frisch elasticity of labour supply
ξ	0.6	degree of external habit formation
$(1+\phi_w)/\phi_w$	6	elasticity of substitution between labour varieties
θ_w	0.7	Calvo probability for wages
ζ_w	0.58	indexation parameter for wages
Producers		
α	0.353	product elasticity with respect to capital
$(1+\phi)/\phi$	6	elasticity of substitution between product varieties
δ	0.025	depreciation rate
κ	5.74	investment adjustment cost
θ	0.66	Calvo probability for prices
ζ	0.24	indexation parameter for prices
Taylor rule		
γ_R	0.8	interest rate smoothing
γ_π	1.5	response to inflation
γ_y	0.5	response to GDP
Financial sector - EFP		
μ	0.12	monitoring costs
ν	0.977	survival rate for entrepreneurs
σ_{a_E}	0.27	steady state st. dev. of idiosyncratic productivity
T_E	0.03	transfers to entrepreneurs
Financial sector - CC		
β_E	0.975	entrepreneurs discount factor
μ_L	209	elasticity of substitution between loan varieties
m_f	0.7	steady state LTV
γ_E	2.85	measure of entrepreneurs

Table 2: Stochastic processes

Parameter	Values	Description
Common shocks - same in both models		
ρ_A	0.95	productivity shock
σ_A	0.007	productivity shock
ρ_G	0.95	government spending shock
σ_G	0.012	government spending shock
σ_R	0.001	monetary policy shock
Financial sector shocks - EFP		
ρ_ν	0.76	net worth shock
σ_ν	0.008	net worth shock
ρ_E	0.81	entrepreneur riskiness shock
σ_E	0.010	entrepreneur riskiness shock
Financial sector shocks - CC		
ρ_{m^F}	0.96	LTV shocks
σ_{m^F}	0.027	LTV shocks
ρ_{z^F}	0.85	spread shocks
σ_{z^F}	0.001	spread shocks

Table 3: Steady state ratios

Variable	Values
Consumption share in GDP	0.63
Government expenditure share in GDP	0.16
Steady state inflation rate	1.006
Investment share in GDP	0.21
External finance premium (EFP)/Spread (CC)	0.005
Capital to debt ratio	2.0
Entrepreneurs share in total consumption	0.16

Table 4: Variance decomposition: NK version

	Productivity	Government	Monetary
GDP	98.6	0.9	0.5
Labour	95.6	3.4	1.0
Consumption	89.2	10.2	0.6
Investment	93.8	5.9	0.3
Inflation	99.7	0.3	0.0
Interest rate	98.9	0.6	0.5
Price of capital	79.1	7.3	13.6

Table 5: Variance decomposition: EFP version

	Productivity	Government	Monetary	Net worth	Riskiness
GDP	36.6	0.7	1.0	55.0	6.6
Labour	76.9	3.0	0.9	17.0	2.2
Consumption	55.9	6.7	0.4	35.3	1.7
Investment	1.8	1.2	0.8	86.6	9.6
Loans	28.4	0.6	0.4	64.2	6.4
Inflation	70.0	0.0	0.2	29.5	0.2
Interest rate	71.0	0.2	0.9	27.8	0.1
Spread	5.5	0.0	0.2	26.9	67.3
Price of capital	13.3	1.6	3.8	23.1	58.1

Table 6: Variance decomposition: CC version

	Productivity	Government	Monetary	LTV	Spread
GDP	43.8	0.4	1.2	52.8	1.8
Labour	51.3	0.8	1.1	45.5	1.2
Consumption	47.1	5.4	1.1	45.0	1.4
Investment	30.0	1.1	1.0	61.8	6.1
Loans	7.0	0.3	0.1	92.0	0.7
Inflation	83.7	0.1	0.1	15.5	0.7
Interest rate	79.6	0.1	0.3	19.6	0.4
Spread	0.0	0.0	0.0	0.0	100.0
Price of capital	16.4	0.1	1.0	80.8	1.7

Table 7: Moments of the model generated variables against the data

	Data	NK	EFP	CC
Standard deviations				
GDP	2.26	1.85	1.92	2.65
Labour	2.41	1.90	2.11	3.84
Consumption	2.33	1.56	2.03	2.42
Investment	9.22	4.34	7.82	6.52
Loans	7.80	-	7.80	7.80
Inflation	0.80	1.76	1.64	1.91
Interest rate	0.81	1.56	1.42	1.88
Spread	0.24	-	0.24	0.24
Price of capital	-	0.86	2.09	24.30
Autocorrelations				
GDP	0.91	0.99	0.99	0.76
Employment	0.93	0.82	0.86	0.61
Consumption	0.94	0.99	0.99	0.74
Investment	0.96	0.99	0.99	0.85
Loans	0.99	-	0.99	0.99
Inflation	0.70	0.94	0.94	0.93
Interest rate	0.94	0.99	0.99	0.98
Spread	0.85	-	0.85	0.85
Price of capital	-	0.60	0.72	-0.06
Correlations with GDP				
GDP	1.00	1.00	1.00	1.00
Employment	0.68	-0.61	-0.35	0.47
Consumption	0.85	0.89	0.50	0.90
Investment	0.79	0.93	0.76	0.91
Loans	0.23	-	-0.03	0.00
Inflation	0.23	-0.87	-0.83	-0.42
Interest rate	0.04	-0.97	-0.88	-0.49
Spread	-0.29	-	-0.38	-0.12
Price of capital	-	0.34	0.28	0.59

Table 8: Output components from the business cycle accounting

	Data	NK	EFP	CC
Standard Deviations				
All wedges	2.28	1.81	1.94	2.49
Efficiency	1.20	2.66	2.61	2.63
Labour	1.67	0.99	0.98	2.04
Government	0.25	0.18	0.18	0.19
Investment	1.17	0.16	1.62	0.76
Autocorrelations				
All wedges	0.93	0.99	0.99	0.74
Efficiency	0.92	0.98	0.98	0.98
Labour	0.97	0.85	0.86	0.62
Government	0.97	0.90	0.90	0.90
Investment	0.99	0.99	0.99	0.94
Correlations with output				
All wedges	1.00	1.00	1.00	1.00
Efficiency	0.84	0.96	0.69	0.51
Labour	0.57	-0.65	-0.63	0.42
Government	0.10	0.13	0.10	0.02
Investment	0.25	-0.70	0.46	0.38
Variance decomposition				
All wedges	100.0	100.0	100.0	100.0
Efficiency	44.3	140.5	92.2	53.9
Labour	42.0	-35.7	-31.4	34.4
Government	1.1	1.3	1.0	0.1
Investment	12.4	-1.6	38.2	11.5

Figure 1: Productivity Shock IRF

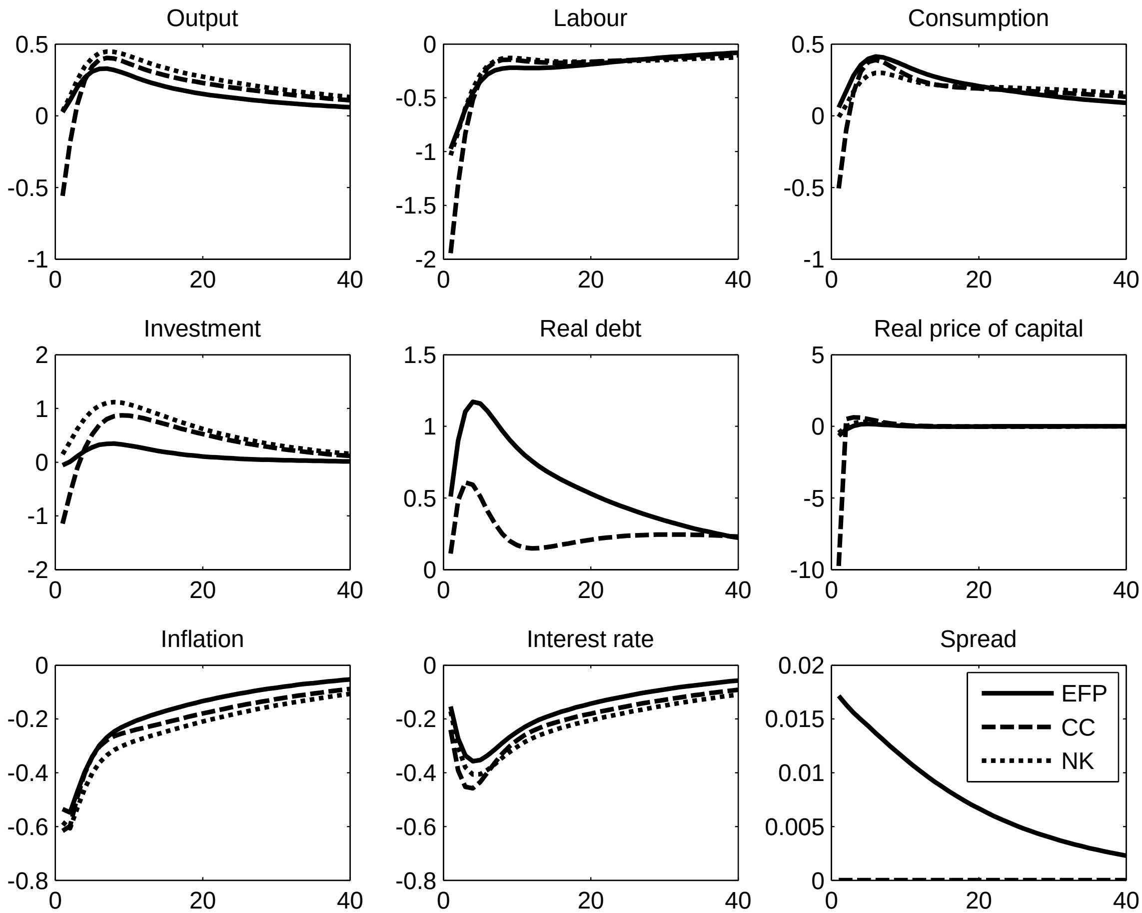

Figure 2: Monetary Shock IRF

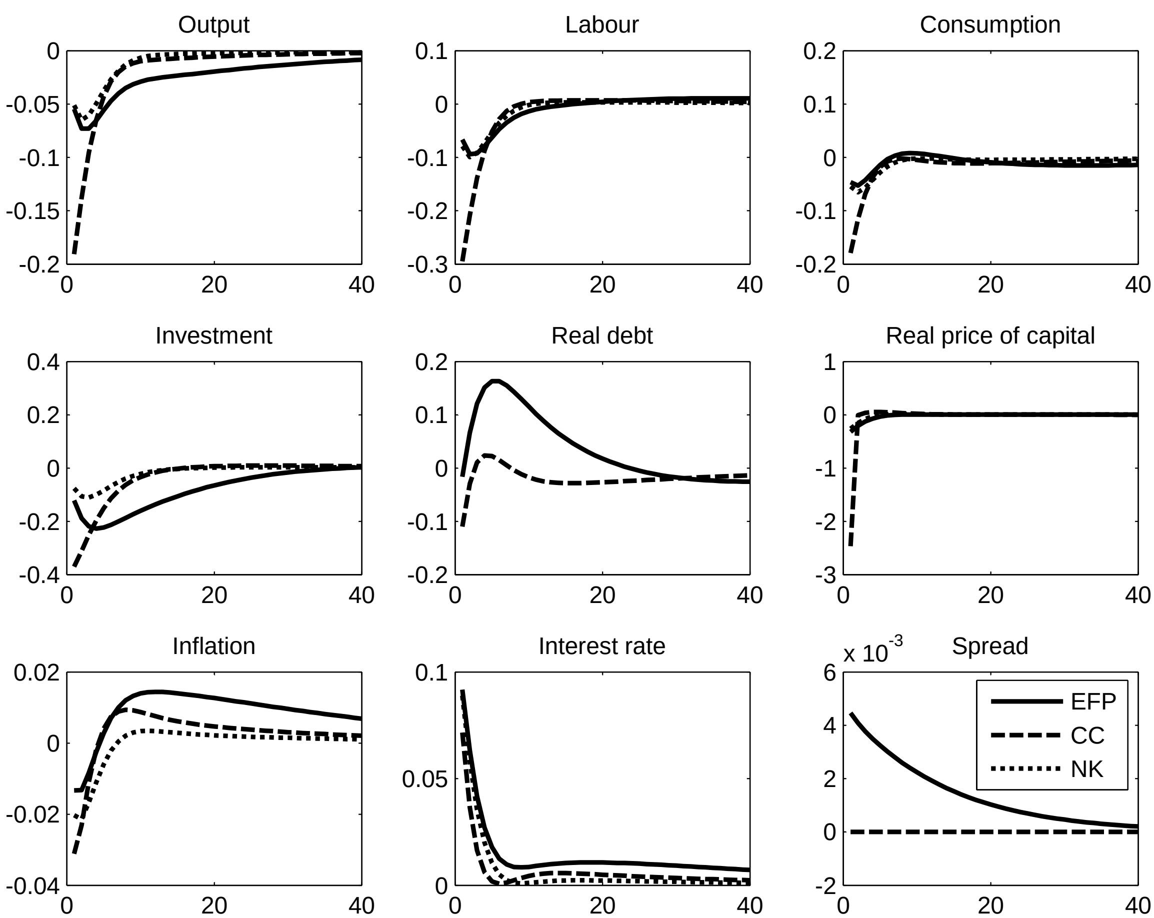

Figure 3: Net Worth (EFP) and LTV (CC) Shock IRFs

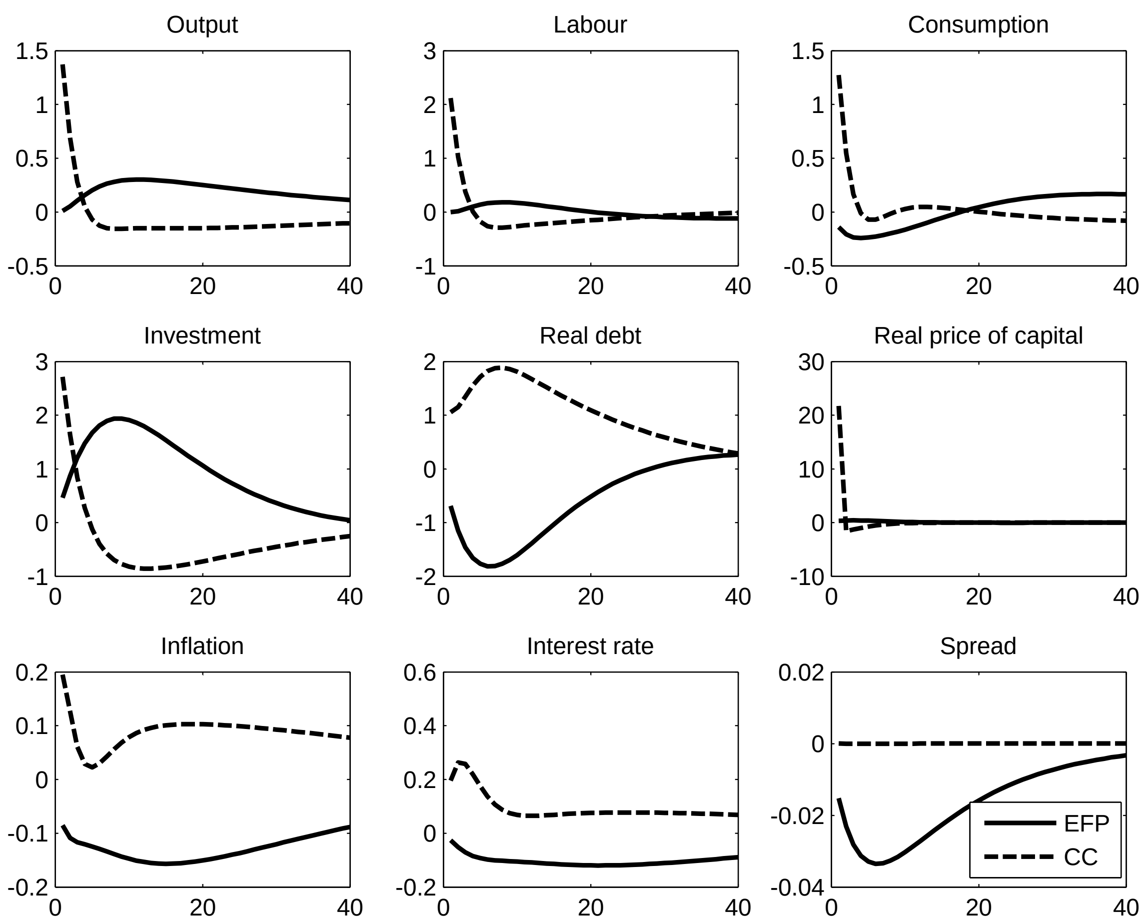

Figure 4: Entrepreneur Riskiness (EFP) and Spread (CC) Shock IRFs