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in a Monetary Union

Nikolay Hristov  
Oliver Hülsewig  
Timo Wollmershäuser

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# Financial Frictions and Inflation Differentials in a Monetary Union

## Abstract

This paper employs a stylized New Keynesian DSGE model for a monetary union to analyze whether cyclical inflation differentials can be explained by cross-country differences concerning the characteristics of financial markets. Our results suggest that empirically plausible degrees of heterogeneity with respect to two important credit market characteristics - namely the fraction of borrowers and to a lesser extent the loan-to-value ratio - generate inflation differentials that are similar to those implied by structural differences with respect to price inertia and the degree of competitiveness. Hence, the characteristics of financial markets should be seen as a possible alternative explanation for the observable inflation dispersion in the EMU.

JEL-Code: E32, E44, E52, F41, G10.

Keywords: monetary union, inflation, differentials, collateral constraints, cross-country heterogeneity, household indebtedness.

*Nikolay Hristov*  
*Ifo Institute for Economic Research at the*  
*University of Munich*  
*Poschingerstrasse 5*  
*Germany – 81679 Munich*  
*hristov@ifo.de*

*Oliver Hülsewig*  
*University of Applied Sciences Munich*  
*Department of Business Administration*  
*Am Stadtpark 20*  
*Germany – 81243 Munich*  
*oliver.huelsewig@hm.edu*

*Timo Wollmershäuser*  
*Ifo Institute for Economic Research at the*  
*University of Munich*  
*Poschingerstrasse 5*  
*Germany – 81679 Munich*  
*wollmershaeuser@ifo.de*

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# 1 Introduction

The European Central Bank (ECB) is responsible for achieving price stability in the euro area as a whole. However, unless the euro area is a homogenous economic entity, stabilization at the aggregate level does not preclude that the price level across member countries can evolve differently (European Central Bank, 2005). As a particular concern for monetary policy, differences across countries regarding economic structures, rigidities or institutional regulations potentially cause asymmetric national price adjustments, in the short as well as in the long run. Such a dispersion can have undesirable consequences, like persistent distortions in the development of relative prices, which can trigger significant welfare losses.

Several potential sources of long-run inflation dispersion within a monetary union have so far been identified in the literature (European Central Bank, 2003; Hofmann and Remsperger, 2005). Examples are different growth rates in total factor productivity across countries and across sectors (the Balassa-Samuelson effect), convergence in tradable goods prices due to increased economic integration, or adjustments in non-tradable goods prices in the wake of real income convergence. Beyond these differences in trend inflation there also seem to be substantial short-run, or cyclical, inflation differentials (Rogers, 2002; Ortega, 2003). One potential source of differences in the evolution of inflation rates as well as other variables at business cycles frequencies are asymmetric (or country-specific) shocks.<sup>1</sup> However, irrespective of the specific nature of the exogenous disturbances hitting a monetary union, different price adjustment processes may be also the result of heterogeneities with respect to important structural parameters (Andres, Ortega, and Valles, 2008; Angeloni and Ehrmann, 2007).

This paper analyses whether cross-country heterogeneity of financial market characteristics within the European Monetary Union (EMU) is a potential source of cyclical inflation dispersion in the presence of symmetric shocks. We employ a stylized New Keynesian DSGE model for a monetary union with two large member states differing from each other by the structural parameters governing the access to credit and the proportion of households holding debt. Although, Arnold

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<sup>1</sup>This possibility has so far been extensively discussed in the literature on optimum currency areas. See Jondeau and Sahuc (2007), Mongelli (2005) and the references therein.

and de Vries (1999) argue that the regime shift to EMU has possibly triggered convergence in financial structures of the member countries, there is sufficient empirical evidence on the euro area that heterogeneity in the characteristics of national financial markets is still substantial. Mojon (2000) shows that the monetary transmission process in the euro area is affected by differences in national financial structure. The OECD (2006), Girouard et al. (2006) and Crook and Hochguertel (2007) document that the proportion of households holding debt varies greatly across the member states of the EMU. Moreover, the IMF (2008) and Calza et al. (2009) demonstrate that the same applies to the institutional characteristics of national mortgage markets with the typical loan-to-value ratios also differing substantially from one country to another.

Our stylized model for the EMU is inspired by Monacelli (2009), as we consider two types of households in each member country, namely savers and borrowers, which differ from each other in their degree of patience, and two types of firms, which produce differentiated goods in two sectors, namely a consumption goods sector and a sector for housing services. The framework is related to the work of Bernanke et al. (1996), Kiyotaki and Moore (1997), Iacoviello (2005) and Campbell and Hercowitz (2005), who emphasize that macroeconomic fluctuations are potentially amplified by financial frictions. Generally, since lenders are likely to have little information on the creditworthiness of a borrower, they require borrowers to set forth their ability to repay their debt, which may take the form of collateralized assets. Therefore, given cross-country differences in financial characteristics, common exogenous shocks can have a quite asymmetric impact on the value of collateral assets and thus the ability to borrow across member states. The likely implication is an asymmetric country-specific pass-through of economic disturbances.

Indeed, our results suggest that cross-country heterogeneities with respect to the characteristics of financial markets are able to explain cyclical inflation differentials arising in a monetary union. In particular, we observe that in the case of monetary shocks the response of inflation is more pronounced in member states with a larger share of borrowers and/or a higher loan-to-value ratio. If a common technology shock hits the monetary union, the reverse is true.

Our work is akin to Andres et al. (2008) and Angeloni and Ehrmann (2007),

who find that differences across countries concerning economic structure, such as the degrees of competition and openness or the intensity of nominal rigidity can generate inflation differentials even in response to symmetric shocks. Andres et al. (2008) employ a model – a fixed exchange rate version of the framework of Obstfeld and Rogoff (1995) – in which the world is composed of two countries with a common monetary authority. Each country produces differentiated goods traded in monopolistic competitive markets. Price discrimination occurs due to country-specific price inertia, triggered by different price adjustment costs and differentiated country-specific degrees of competition. They find that inflation reacts faster in the country with more competitive markets and with lower price adjustment costs when the economy is subject to a symmetric monetary policy shock. Angeloni and Ehrmann (2007) consider a model in which each country is modeled separately by means of an aggregate supply and an aggregate demand equation. The model is closed with a monetary policy rule. They estimate their model using panel techniques and find – inter alia – that inflation dispersion can be related to different degrees of price flexibility.

In contrast to Andres et al. (2008) and Angeloni and Ehrmann (2007), we focus explicitly on the role of financial frictions across countries in shaping the pass-through of shocks to inflation. To our best knowledge, such an analysis has not been performed before. According to our results, empirically plausible degrees of heterogeneity with respect to the proportion of households holding debt and the loan-to-value ratio generate inflation differentials of similar magnitude and persistence as implied by the structural differences considered in Andres et al. (2008) and Angeloni and Ehrmann (2007). Thus, heterogeneity in the characteristics of financial markets across countries in a monetary union should be seen as an alternative explanation of the observable cyclical inflation dispersion in the EMU.

The remainder of the paper is organized as follows. In Section 2 our stylized model for the EMU is set out. Section 3 describes the calibration. We also provide a brief review of the empirical evidence on differences in the structure of financial markets across the member states of the EMU. In Section 4 we discuss our simulation results. Section 5 concludes.

## 2 The Model

The model consists of two countries that form a currency union with a single central bank. The countries are labeled  $H$  and  $F$  and are of size  $n$  and  $1 - n$ . There is no possibility of migration across countries.

Every country consists of two types of households: savers of measure  $\omega$  and borrowers of measure  $1 - \omega$ , who both consume and work. Firms are partitioned into final good producers and intermediate good producers. Final good producers operate in two sectors – a consumption goods sector and a housing sector – under perfect competition. Intermediate good producers produce differentiated sectoral goods under monopolistic competition. They have some market power over their own price, but face frictions as in Calvo (1983), which implies a staggered price setting. The continuum of intermediate good producers is indexed by  $h \in [0, n]$  in the home country, and by  $f \in (n, 0]$  in the foreign country.

As in Iacoviello (2005) and Monacelli (2009), we assume that the two types of households feature heterogeneous preferences, with borrowers being more impatient than savers. Borrowers are constrained in their access to credit because they are obliged to deposit collateral, which is tied to the value of their existing stock of housing. In what follows, we present the home country block of the model only, since the foreign country block is identical. In case foreign country variables are used, these are denoted by an asterisk.<sup>2</sup>

### 2.1 Savers

The representative saver in the home country maximizes the following utility function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \gamma \log(C'_t) + (1 - \gamma) \log(D'_t) - \frac{\varphi'_c}{1 + \eta} (N'_{ct})^{1+\eta} - \frac{\varphi'_d}{1 + \eta} (N'_{dt})^{1+\eta} \right], \quad (1)$$

where  $C'_t$  denotes an index of consumption goods,  $D'_t$  is the stock of housing,  $N'_{ct}$  and  $N'_{dt}$  denote hours worked in the consumption goods and the housing sector respectively,  $\beta$  is the discount factor,  $\gamma$  is the share of consumption goods,  $\eta$  is the inverse elasticity of labor supply and  $\varphi'_c$  and  $\varphi'_d$  are parameters indexing the

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<sup>2</sup>Appendix A summarizes the complete set of model equations.

preference for hours worked.<sup>3</sup> Total hours worked supplied by the representative saver are given by  $N'_t$ , such that  $N'_t = N'_{ct} + N'_{dt}$ .

The index of consumption goods is composed of domestic and foreign consumption goods given by:

$$C'_t = \left[ \nu^{\frac{1}{b}} (C'_{Ht})^{\frac{b-1}{b}} + (1 - \nu)^{\frac{1}{b}} (C'_{Ft})^{\frac{b-1}{b}} \right]^{\frac{b}{b-1}}, \quad (2)$$

where  $C'_{Ht}$  is consumption of home produced consumption goods,  $C'_{Ft}$  is consumption of foreign produced consumption goods,  $\nu$  denotes the home bias in preferences and  $b$  is the elasticity of substitution.<sup>4</sup>

The budget constraint of the representative saver in nominal terms is:

$$\begin{aligned} P_{ct} C'_t + P_{dt} [D'_t - (1 - \delta) D'_{t-1}] + A'_t + \frac{\phi}{2} P_{ct} \left( \frac{A'_t}{P_{ct}} \right)^2 + B'_t \\ = W_{ct} N'_{ct} + W_{dt} N'_{dt} + R_{t-1} A'_{t-1} + R_{Ht-1} B'_{t-1} + \omega^{-1} \Gamma'_t, \end{aligned} \quad (3)$$

where  $P_{ct}$  is the price index of consumption goods,  $P_{dt}$  is the price index of housing,  $A_t$  are bonds traded across countries,  $B_t$  is the amount of credit lent to the group of borrowers,  $\delta$  is the depreciation rate on the housing stock,  $W_{ct}$  and  $W_{dt}$  denote the nominal wage in the consumption goods and the housing sector respectively.  $\Gamma_t$  are profits from firms. We introduce a small quadratic adjustment cost of international bonds, whose relevance is of measure  $\phi > 0$ . These costs drive a wedge between the international gross interest rate  $R_t$  and the domestic gross interest rate  $R_{Ht}$ .<sup>5</sup>

For the representative saver the first-order conditions are given by:

$$q_t = \frac{1 - \gamma}{\gamma} \frac{C'_t}{D'_t} + \beta(1 - \delta) E_t \left[ q_{t+1} \frac{C'_{t+1}}{C'_{t+1}} \right], \quad (4)$$

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<sup>3</sup>The assumption of differentiated types of labor supply,  $N_{ct}$  and  $N_{dt}$ , is needed to ensure that in the face of a contractionary monetary shock production in both sectors decline. Differentiated types of working hours imply that wages are not necessarily equal across sectors which dampens the relative price movements and the resulting cross sectoral substitution effects that would otherwise lead to a negative correlation between sector specific outputs. See the Appendix B for a discussion.

<sup>4</sup>We assume that consumption goods are all tradable.

<sup>5</sup>The reason to include adjustment costs for international bonds is to achieve the stationarity of the financial system. See Schmitt-Grohe and Uribe (2003).

$$1 = \beta E_t \left[ \frac{C'_t}{C'_{t+1}} \frac{P_{ct}}{P_{ct+1}} \right] R_{Ht}, \quad (5)$$

$$1 = \beta E_t \left[ \frac{C'_t}{C'_{t+1}} \frac{P_{ct}}{P_{ct+1}} \right] R_t - \phi a'_t, \quad (6)$$

$$\varphi'_c (N'_{ct})^\eta C'_t = \gamma w_{ct}, \quad (7)$$

$$\varphi'_d (N'_{dt})^\eta C'_t = \gamma w_{dt}, \quad (8)$$

where  $q_t = P_{dt}/P_{ct}$  is the real housing price while  $w_{ct}$  and  $w_{dt}$  denote the real wage in the consumption goods and the housing sector respectively. Combining expressions (5) and (6) gives:

$$R_{Ht} = \frac{R_t}{1 + \phi a'_t}. \quad (9)$$

The allocation of consumer goods expenditures between domestic and foreign produced goods is:

$$C'_{Ht} = \nu \left( \frac{P_{Ht}}{P_{ct}} \right)^{-b} C'_t \quad (10)$$

and

$$C'_{Ft} = (1 - \nu) \left( \frac{P_{Ft}}{P_{ct}} \right)^{-b} C'_t, \quad (11)$$

where  $P_{Ht}$  and  $P_{Ft}$  are the price indices of home and foreign produced consumption goods, respectively. The utility maximization problem of the representative saver in the foreign country is similar as we assume that the functional forms for preferences are identical across countries.

## 2.2 Borrowers

The representative borrower maximizes the utility function:

$$E_0 \sum_{t=0}^{\infty} v^t \left[ \gamma \log(C''_t) + (1 - \gamma) \log(D''_t) - \frac{\varphi''_c}{1 + \eta} (N''_{ct})^{1+\eta} - \frac{\varphi''_d}{1 + \eta} (N''_{dt})^{1+\eta} \right], \quad (12)$$

where  $C''_t$  is an index of consumption goods,  $D''_t$  is the stock of housing,  $N''_{ct}$  and  $N''_{dt}$  are again the amounts of sector-specific hours worked and  $v$  is the discount



factor, for which we assume that  $v < \beta$ . This inequality ensures that for small enough exogenous disturbances the collateral constraint is always binding. The index of consumption goods is given by:

$$C_t'' = \left[ \nu^{\frac{1}{b}} (C_{Ht}'')^{\frac{b-1}{b}} + (1-\nu)^{\frac{1}{b}} (C_{Ft}'')^{\frac{b-1}{b}} \right]^{\frac{b}{b-1}}. \quad (13)$$

The budget constraint of the representative borrower expressed in nominal terms is:<sup>6</sup>

$$P_{ct}C_t'' + P_{dt}[D_t'' - (1-\delta)D_{t-1}''] + B_t'' = W_{ct}N_{ct}'' + W_{dt}N_{dt}'' + R_{Ht-1}B_{t-1}''. \quad (14)$$

Borrowers face a restriction on borrowing, which is given by the collateral constraint:

$$R_{Ht}B_t'' \leq (1-\xi)E_t[P_{dt+1}(1-\delta)D_t''], \quad (15)$$

where  $\xi \in (0, 1)$ . The collateral constraint implies that borrowing is tied to the expected future value of the stock of housing after depreciation. According to Calza et al. (2009) this type of constraint can be justified on the basis of limited enforcement. Since the borrower can possibly deny to repay the debt in case of default, requiring a collateral ex-ante serves as an insurance against that temptation. The parameter  $\xi$  indicates the share of the housing stock that cannot be used as collateral, which means that  $1 - \xi$  provides a proxy for the loan-to-value ratio.

For the representative borrower the relevant first-order conditions are summarized by:

$$q_t = \frac{1-\gamma}{\gamma} \frac{C_t''}{D_t''} + (1-\xi)(1-\delta)\psi_t E_t[q_t \pi_{dt+1}] + v(1-\delta)E_t \left[ q_{t+1} \frac{C_t''}{C_{t+1}''} \right], \quad (16)$$

$$1 = vE_t \left[ \frac{C_t''}{C_{t+1}''} \frac{P_{ct}}{P_{ct+1}} \right] R_{Ht} + \psi_t R_{Ht}, \quad (17)$$

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<sup>6</sup>We follow Aspachs-Bracons and Rabanal (2010) and Paries and Notarpietro (2008) and assume that borrowers have no access to international financial markets and are only able to borrow on the domestic bond market.

$$\varphi_c''(N_{ct}'')^\eta C_t'' = \gamma w_{ct}, \quad (18)$$

$$\varphi_d''(N_{dt}'')^\eta C_t'' = \gamma w_{dt}. \quad (19)$$

$\psi_t$  denotes the Lagrangean multiplier associated with the collateral constraint.<sup>7</sup>

Finally, the allocation of consumer goods expenditures between domestic and foreign produced goods is:

$$C_{Ht}'' = \nu \left( \frac{P_{Ht}}{P_{ct}} \right)^{-b} C_t'', \quad (20)$$

and

$$C_{Ft}'' = (1 - \nu) \left( \frac{P_{Ft}}{P_{ct}} \right)^{-b} C_t''. \quad (21)$$

### 2.3 Aggregate Consumption, the Consumer Price Index, and Terms of Trade

Aggregate consumption by households is a weighted average of the corresponding consumption expenditures of each type of consumer, which is given by:

$$C_t \equiv \omega C_t' + (1 - \omega) C_t''. \quad (22)$$

Along similar lines we have:

$$C_{Ht} \equiv \omega C_{Ht}' + (1 - \omega) C_{Ht}'', \quad \text{and} \quad C_{Ft} \equiv \omega C_{Ft}' + (1 - \omega) C_{Ft}''. \quad (23)$$

The price index of consumption goods is:

$$P_{ct} = [\nu (P_{Ht})^{1-b} + (1 - \nu) (P_{Ft})^{1-b}]^{\frac{1}{1-b}}. \quad (24)$$

The terms of trade are defined as:

$$\tau_t = \frac{P_{Ft}}{P_{Ht}}. \quad (25)$$

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<sup>7</sup>Note that the steady-state value of the Lagrangean multiplier  $\psi_t$  is given by  $\psi = \beta - v > 0$  which implies that the credit constraint is binding in the stationary equilibrium.

## 2.4 Final Good Producers

Final good producers operate in each sector  $j = c, d$  under perfect competition. The technology to produce the aggregate final goods is given by:

$$Y_{jt} \equiv \left[ \left( \frac{1}{n} \right)^{\frac{1}{\theta_j}} \int_0^n Y_{jt}(h)^{\frac{\theta_j-1}{\theta_j}} dh \right]^{\frac{\theta_j}{\theta_j-1}}, \quad (26)$$

for  $j = c, d$ , where  $\theta_j$  is the elasticity of substitution.

Profit maximization by final good producers delivers the following demand functions for individual intermediate consumption goods:

$$Y_{ct}(h) = \frac{1}{n} \left( \frac{P_{Ht}(h)}{P_{Ht}} \right)^{-\theta_c} Y_{ct}, \quad (27)$$

and individual intermediate housing services:

$$Y_{dt}(h) = \frac{1}{n} \left( \frac{P_{dt}(h)}{P_{dt}} \right)^{-\theta_d} Y_{dt}. \quad (28)$$

The corresponding price indices are given by:

$$P_{Ht} = \left[ \frac{1}{n} \int_0^n P_{Ht}(h)^{1-\theta_c} dh \right]^{\frac{1}{1-\theta_c}} \quad \text{and} \quad P_{dt} = \left[ \frac{1}{n} \int_0^n P_{dt}(h)^{1-\theta_d} dh \right]^{\frac{1}{1-\theta_d}}. \quad (29)$$

## 2.5 Intermediate Goods Producers

Intermediate goods producers indexed by  $h \in [0, n]$  produce differentiated goods under monopolistic competition. A generic firm  $h$  in each sector  $j$  has access to the technology:

$$Y_{jt}(h) = \exp(\zeta_t) N_{jt}(h) \quad (30)$$

for  $j = c, d$ , where  $\zeta_t$  is a common technology shock, which is assumed to follow an  $AR(1)$  process in logs:<sup>8</sup>

$$\log(\zeta_t) = \rho_\zeta \log(\zeta_{t-1}) + \varepsilon_t^\zeta. \quad (31)$$

Profit by firm  $h$  is given by:

$$\Pi_{jt}(h) = P_{it}(h) Y_{jt}(h) - W_{jt} N_{jt}(h), \quad (32)$$

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<sup>8</sup>Notice that we neglect sector-specific technology shocks.

where  $i = H$  if  $j = c$  and  $i = d$  if  $j = d$ . The nominal marginal costs are:

$$\text{MC}_{ct}(h) = \exp(\zeta_t)^{-1} W_{ct}, \quad (33)$$

and

$$\text{MC}_{dt}(h) = \exp(\zeta_t)^{-1} W_{dt}. \quad (34)$$

We assume that intermediate goods producers have some market power over their own product, but face price frictions as in Calvo (1983), which implies a staggered price setting. Only a fraction of firms  $1 - \alpha_j$  re-optimize their prices in each period, while the remaining fraction  $\alpha_j$  leave their prices unchanged, where  $j = c, d$ .

**Intermediate Consumption Goods Producers** Firms in the consumption goods sector that set their price optimally face the following maximization problem:

$$E_t \sum_{i=0}^{\infty} \alpha_c^i Q_{i,t+i} Y_{ct+i}(h) \left[ \frac{\tilde{P}_{Ht}(h)}{P_{ct+i}} - \frac{\text{MC}_{ct+i}(h)}{P_{ct+i}} \right], \quad (35)$$

subject to the demand equation:

$$Y_{ct+i}(h) = \frac{1}{n} \left( \frac{\tilde{P}_{Ht}(h)}{P_{Ht+i}} \right)^{-\theta_c} Y_{ct+i}, \quad (36)$$

where  $\tilde{P}_{Ht}(h)$  is the re-optimized price. Notice that  $Q_{i,t+i}$  is the stochastic discount factor that is equal to the intertemporal marginal rate of substitution of the representative saver, who owns the firms.

The optimal choice is given by:

$$E_t \sum_{i=0}^{\infty} \alpha_c^i Q_{i,t+i} Y_{ct+i}(h) \left[ \frac{\tilde{P}_{Ht}(h)}{P_{Ht+i}} \frac{P_{Ht+i}}{P_{ct+i}} - \frac{\theta_c}{\theta_c - 1} \frac{\text{MC}_{ct+i}(h)}{P_{ct+i}} \right] = 0. \quad (37)$$

The price index for domestic consumption goods evolves according to:

$$P_{Ht} = \left[ (1 - \alpha_c)(\tilde{P}_{Ht})^{1-\theta_c} + \alpha_c(P_{Ht-1})^{1-\theta_c} \right]^{\frac{1}{1-\theta_c}}. \quad (38)$$

**Intermediate Housing Producers** Firms in the housing sector face a similar maximization problem, and thus the optimal housing price  $\tilde{P}_{dt}$  and the evolution of the price index of housing  $P_{dt}$  have identical expressions.

## 2.6 Market Clearing Conditions

For the home country, the market clearing condition in the market for consumption goods is:

$$Y_{ct} = nC_{Ht} + (1-n)C_{Ht}^* + n\omega\frac{\phi}{2}a_t'^2 [\nu + (1-\nu)\tau^{1-b}]^{\frac{1}{1-b}}, \quad (39)$$

where  $C_{Ht} = \omega C'_{Ht} + (1-\omega)C''_{Ht}$  and  $C_{Ht}^* = \omega^* C'^*_{Ht} + (1-\omega^*)C''^*_{Ht}$ . The equilibrium in the market for housing services is given by:

$$Y_{dt} = n[\omega(D'_t - (1-\delta)D'_{t-1}) + (1-\omega)(D''_t - (1-\delta)D''_{t-1})]. \quad (40)$$

Hence, total output is:

$$Y_t = \frac{P_{ct}}{P_{yt}}(\nu + (1-\nu)\tau^{1-b})^{\frac{1}{b-1}}Y_{ct} + \frac{P_{ct}}{P_{yt}}q_tY_{dt}. \quad (41)$$

where  $P_{yt}$  denotes the domestic output deflator.

For the foreign country, the analogous conditions are:

$$Y_{ct}^* = (1-n)C_{Ft}^* + nC_{Ft} + (1-n)\omega^*\frac{\phi^*}{2}(a_t'^*)^2 [(1-\nu^*)\tau^{1-b} + \nu^*]^{\frac{1}{1-b}}, \quad (42)$$

$$Y_{dt}^* = (1-n)[\omega^*(D_t'^* - (1-\delta^*)D_{t-1}'^*) + (1-\omega^*)(D_t''^* - (1-\delta^*)D_{t-1}''^*)], \quad (43)$$

$$Y_t^* = \frac{P_{ct}^*}{P_{yt}^*}((1-\nu^*)\tau_t^{b-1} + \nu^*)^{\frac{1}{b-1}}Y_{ct}^* + \frac{P_{ct}^*}{P_{yt}^*}q_tY_{dt}^*, \quad (44)$$

where  $C_{Ft}^* = \omega^* C'^*_{Ft} + (1-\omega^*)C''^*_{Ft}$ ,  $C_{Ft} = \omega C'_{Ft} + (1-\omega)C''_{Ft}$ .

The equilibrium in the labor market is characterized by the equality of labor supply and hours worked:

$$N_{jt} = n[\omega N'_{jt} + (1-\omega)N''_{jt}], \quad (45)$$

for  $j = c, d$ . Market clearing in the international bonds market requires:<sup>9</sup>

$$n\omega A'_t + (1-n)\omega^* A_t'^* \frac{P_{ct}^*}{P_{ct}} = 0, \quad (46)$$

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<sup>9</sup>Notice that the second term on the left hand side of the expression is multiplied by the ratio between home and foreign consumption price levels since  $A_t'^*$  is denominated in units of the foreign consumption good.

while equilibrium in the national debt market is given by:

$$\omega B'_t + (1 - \omega)B''_t = 0. \quad (47)$$

Finally, the evolution of aggregate net foreign assets is:

$$n\omega A'_t = n\omega R_{t-1}A'_{t-1} + (1 - n)P_{Ht}^*C_{Ht}^* - nP_{Ft}C_{Ft}. \quad (48)$$

## 2.7 EMU Aggregates

Total output in the EMU is:

$$Y_t^{EMU} = \kappa_{yt}Y_t + (1 - \kappa_{yt})\frac{P_{ct}^*}{P_{ct}}Y_t^*, \quad (49)$$

where  $\kappa_{yt}$  and  $(1 - \kappa_{yt})P_{ct-1}^*/P_{ct-1}$  are the country-specific weights. The area-wide inflation rate is given by:

$$\pi_{ct}^{EMU} = \kappa_{ct}\pi_{ct} + (1 - \kappa_{ct})\frac{P_{ct-1}^*}{P_{ct-1}}\pi_{ct}^*, \quad (50)$$

where  $\kappa_{ct}$  and  $(1 - \kappa_{ct})P_{ct-1}^*/P_{ct-1}$  denote the country-specific weights.

As the ECB is obliged to maintain price stability in the euro area as a whole, we assume that monetary policy is conducted by means of the following interest rate setting rule:

$$R_t = R \left( \frac{\pi_{ct}^{EMU}}{\pi_c^{EMU}} \right)^{\rho_\pi} \exp(z_t), \quad (51)$$

where  $R_t$  is the gross nominal interest rate and  $R$  denotes its steady-state value.  $\pi_c^{EMU}$  is the steady-state value of the area wide inflation rate and  $z_t$  is a monetary policy shock, which is assumed to follow an  $AR(1)$  process in logs:

$$\log(z_t) = \rho_z \log(z_{t-1}) + \varepsilon_t^z. \quad (52)$$

Given that price stability in the euro area is measured by means of the harmonized consumer price index, we refrain from additionally considering the area-wide house price index.

### 3 Calibration

For both countries, we assume that in the steady state inflation is zero, the trade balance is in equilibrium, and the respective net international positions are balanced. We also assume that the degree of monopolistic competition in both countries concerning the consumption goods sector and the housing sector is the same, which implies that:  $\theta_c = \theta_d = \theta_c^* = \theta_d^*$ .

We assume that the size of each country is identical. Labor supply by savers and borrowers in the symmetric-countries steady state is set to  $1/3$  and the values of the parameters  $\varphi'_j$ ,  $\varphi''_j$ ,  $\varphi'^*_j$  and  $\varphi''^*_j$ , for  $j = c, d$ , are calculated to be consistent with this assumption.<sup>10</sup> The inverse elasticities of labor supply  $\eta$  and  $\eta^*$  are calibrated to 1.

As in Monacelli (2009) and Calza et al. (2009), we assume that the discount factors of savers in both countries  $\beta$  and  $\beta^*$  are 0.99, while the discount factors of borrowers  $v$  and  $v^*$  are 0.98, respectively. The shares of consumption goods  $\gamma$  and  $\gamma^*$  are set equal to 0.85. The elasticities of substitution between home and foreign goods  $b$  and  $b^*$  are calibrated to 1, which implies that these goods are not perfectly substitutable. We assume that the share of home consumption goods  $\nu$  in the home consumption index and the share of foreign consumption goods  $\nu^*$  in the foreign consumption index are identical. Using the information drawn from Jondeau and Sahuc (2008), we calibrate these shares to 0.8. Following Aspachs-Bracons and Rabanal (2010) we set the depreciation rate for housing  $\delta$  and  $\delta^*$  equal to 0.025, respectively. The adjustment costs parameters of international bond holdings  $\phi$  and  $\phi^*$  are calibrated to 0.001.

For the EMU, Alvarez (2008) reports that prices in the member countries remain unchanged over 12 months on average, with a range varying between 11 and 13.5 months. Thus, in the baseline calibration we set the degree of nominal rigidity in the consumption goods sector  $\alpha_c$  and  $\alpha_c^*$  to 0.75, but we also investigate the consequences of differing  $\alpha_c$  and  $\alpha_c^*$  for the emergence of cross-country inflation differentials. As stated by Bils and Klenow (2004) prices in the housing

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<sup>10</sup>When introducing financial market heterogeneity across countries we allow national labor supplies to adjust while holding  $\varphi'_j$ ,  $\varphi''_j$ ,  $\varphi'^*_j$  and  $\varphi''^*_j$  for  $j = c, d$  fixed. Alternatively, one may let these parameters change while holding the steady-state value of labor supply fixed.

sector are generally more flexible. Aspachs-Bracons and Rabanal (2010) estimate the degree of nominal rigidity in the housing sector to around 0.34, while Calza et al. (2009) assume that house prices are completely flexible. Assuming that the degree of nominal rigidity is somewhere in between this range, we calibrate  $\alpha_d$  and  $\alpha_d^*$  to 0.25, respectively.

As regards the reaction function of the central bank, we set  $\rho_\pi$  to 1.5. Since we assume that the shocks are autocorrelated, we calibrate  $\rho_\zeta$  and  $\rho_z$  to 0.9 and 0.5 respectively. Table 1 summarizes the set of calibrated parameters.

Table 1: Benchmark Calibration

Description	Parameter	Value
Discount factor savers	$\beta, \beta^*$	0.99
Discount factor borrowers	$\nu, \nu^*$	0.98
Inverse elasticity of labor supply	$\eta, \eta^*$	1
Weight of consumption goods in utility function	$\gamma, \gamma^*$	0.85
Elasticity of substitution between intermediate goods	$\theta_c, \theta_d, \theta_c^*, \theta_d^*$	10.5
Elasticity of substitution between home and foreign goods	$b, b^*$	1
Share of domestic consumption goods in consumption index	$\nu, \nu^*$	0.8
Size of country H	$n$	0.5
Adjustment cost parameter of international bond holdings	$\phi, \phi^*$	0.001
Depreciation rate for housing	$\delta, \delta^*$	0.025
Calvo parameter in the consumption goods sector	$\alpha_c, \alpha_c^*$	0.75
Calvo parameter in the housing sector	$\alpha_d, \alpha_d^*$	0.25
Reaction function of the central bank	$\rho_\pi$	1.5
Autocorrelation of technology shock	$\rho_\zeta$	0.9
Autocorrelation of monetary policy shock	$\rho_z$	0.5
Standard error of technology shock		1%
Standard error of monetary policy shock		1%

Most empirical studies performing comparisons of country-specific financial market characteristics within the EMU conclude that there are substantial differences across member states with respect to the parameters shaping the credit market in our model economy, namely the share of indebted households  $1 - \omega$  and the loan-to-value ratio  $1 - \xi$ . Due to limited data availability (especially regarding micro data) these papers differ in the set of countries and/or variables as



well as the time period considered. Accordingly some differences in the estimated shares of borrowers and loan-to-value ratios arise. The degree of heterogeneity with respect to these two parameters, however, is almost the same across studies.

Girouard et al. (2006) provide data on the fraction of households holding debt by age group in several EMU countries. By combining this data with the country-specific age profiles<sup>11</sup> we arrive at the fraction of indebted households. This fraction varies from about 25 % in Germany and Italy to more than 50 % in Spain and Finland (see Table 2, column 5). Based on household survey-data covering the period 1991 - 2006, Crook and Hochguertel (2007) report average shares of borrowers of 65.3 % in the Netherlands and 23.4% in Italy. The estimated value for Spain in 2003 equals 43.6 %. The share of households holding mortgage debt also differs substantially across member states with Italy and Germany constituting the one extreme and the Netherlands the other. Household debt – expressed as a ratio of disposable income – too, varies greatly, ranging from about 60 % in Italy to a high of 246 % in the Netherlands. Given the markable cross-country differences in the fraction of households holding debt, we allow the corresponding fractions,  $1 - \omega$  and  $1 - \omega^*$ , to vary in a range from 0.2 to 0.6. The baseline calibration corresponds to the symmetric case with an intermediate value  $1 - \omega = 1 - \omega^* = 0.4$ , which is the arithmetic average over the available observations on country-specific fractions of borrowers, given in column 5 of Table 2. This value is lower than the ad hoc value of 0.5 typically assumed in calibrated DSGE models for the Euro Area (Calza et al. (2009), Devreux and Yetman (2009), Monacelli (2006), Rubio (2009) and Sterk (2010)). However the value is somewhat larger than the Bayesian estimates obtained by Paries and Notarpietro (2008), Coenen and Straub (2005) and Forni et al. (2007) who find that the share of borrowers in the EMU is between 0.24 and 0.37.

The heterogeneity concerning the loan-to-value ratios is also substantial. According to Calza et al. (2009) the ratio imposed on new mortgage loans ranges from about 50 % in Italy to 90 % in the Netherlands (see Table 2). Based on data for 2003 and 2004, Osborne (2005) and Crook and Hochguertel (2007) report similarly strong differences in the loan-to-value ratios observed in the mortgage-

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<sup>11</sup>We use data on the number of persons belonging to each age group (0-34, 35-44, 45-54, 55-64, 65-∞) provided by the OECD: <http://stats.oecd.org/index.aspx?r=52086>.

loan market. According to their results these ratios range from 55% in Italy to 83% in Belgium and Portugal and 90% in the Netherlands while both, Germany and France, exhibit an intermediate loan-to-value ratio of 67%. In light of this evidence we allow the loan-to-value ratios  $1 - \xi$  and  $1 - \xi^*$  to vary in a range from 0.5 to 0.9. The loan-to-value ratio in the baseline case with symmetric-countries is set to 0.75 which is consistent with the choice usually made in calibration exercises for the Euro Area (Devreux and Yetman (2009), Monacelli (2006, 2009), Aslam and Santoro (2008)).

Table 2: Financial Market Characteristics

Country	Household Debt <sup>(1)</sup>	Share of Households		Total Debt <sup>(3)</sup>	Loan-To-Value Ratio
		Mortgage Debt <sup>(2)</sup>	Other Debt <sup>(2)</sup>		
Finland	89	30.3	38.7	58.3	75
France	89	29.7	31.5	–	75
Germany	107	26	16	24.6	70
Ireland	141	34.1	29.4	–	70
Italy	59	11.9	12.9	25.2	50
Netherlands	246	47.2	25.2	45.5	90
Spain	107	22.8	23	51.8	70

*Notes:* <sup>(1)</sup> OECD (2006). Measured in percent of annual disposable income. Debt refers to total liabilities outstanding at the end of the period. Data refers to 2005, except for Spain, which refers to 2004. <sup>(2)</sup> OECD (2006). Measured in percent. Some households may hold both categories of debt. <sup>(3)</sup> Own computations based on data provided by Girouard et al. (2006)) and the OECD (<http://stats.oecd.org/index.aspx?r=52086>). Data refers to: 2004 for Finland, Italy and the Netherlands, 2003 for Germany, and 2002 for Spain. Measured in percent. <sup>(4)</sup> Calza, Monacelli, and Stracca (2009). Measured in percent.

## 4 Results

In a monetary union several reasons for explaining cyclical inflation differentials are conceivable. Angeloni and Ehrmann (2007) and Andres et al. (2008) point out that differences in economic structures across countries, such as the degree of competition, nominal rigidities and real rigidities, potentially cause national inflation rates to adjust differently in response to symmetric shocks. In contrast, Jondeau and Sahuc (2007) argue that the most important source of heterogeneity in the adjustment of inflation rates across countries are asymmetric shocks. Rabanal (2009) finds that particularly country-specific productivity shocks in the consumption goods sector matter. However, these results are derived from estimated small-scale DSGE models in which financial frictions are neglected.

Based on our model we seek to explore whether inflation differentials in a monetary union are additionally caused by heterogeneity across countries regarding the characteristics of financial markets, such as the proportion of households holding debt or the loan-to-value ratio. We start by considering a model specification with frictionless financial markets, but with national differences concerning nominal rigidities and the degree of competition. This allows us to facilitate comparison with Andres et al. (2008) for the case of symmetric shocks.

### 4.1 Asymmetric Countries without Financial Frictions

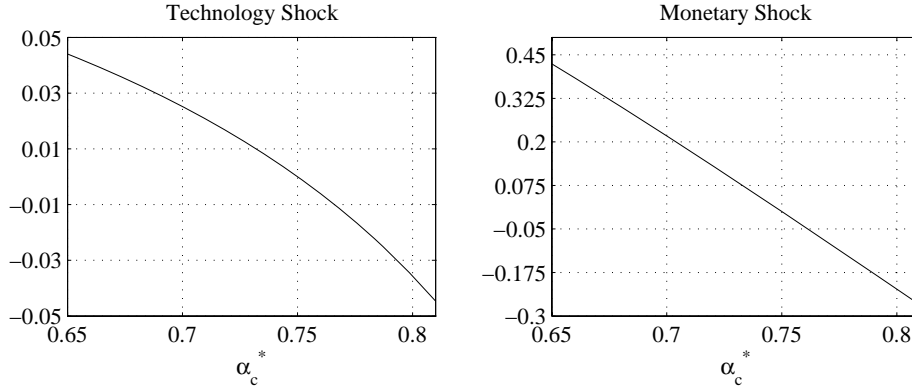
As in Andres et al. (2008), we focus on a model for a monetary union in which differences across the member countries are assumed to emerge with respect to price inertia. We set the Calvo parameter in the home country to  $\alpha_c = 0.75$ , while the Calvo parameter in the foreign country is allowed to vary  $\alpha_c^* \in [0.65, 0.81]$ .<sup>12</sup> Since we neglect financial frictions the shares of borrowers in both countries are set to zero.

Figure 1 depicts the impact inflation differentials under both, a common technology and a common monetary policy shock. The inflation differential is substantial and varies with the degree of price inertia. This finding is similar to

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<sup>12</sup>The range  $\alpha_c^* \in [0.65, 0.81]$  implies the same degrees of price stickiness as those considered by Andres et al. (2008).

Figure 1: Impact Inflation Differential:  $\pi_c - \pi_c^*$



*Notes:* Model for a monetary union without financial frictions, but with heterogenous Calvo Parameters ( $\alpha_c = 0.75$ ). Impact differentials between annualized inflation rates measured in percentage points.

Andres et al. (2008), however some minor differences arise because we additionally account for a housing sector and assume Calvo pricing instead of quadratic price adjustment costs.

Interestingly, our model implies that the impact inflation differential arising from cross-country differences with respect to the degree of monopolistic competition  $\theta_c$  and  $\theta_c^*$  is nil. This is in sharp contrast to Andres et al. (2008), who emphasize that variations in the degree of monopolistic competition is the most important factor for explaining inflation differentials.<sup>13</sup> This discrepancy can be related to the manner of modeling price stickiness. With Calvo pricing the degree of monopolistic competition has a zero first-order effect on the model dynamics, while with quadratic price adjustment costs the degree of monopolistic competition enters the model dynamics.

<sup>13</sup>They obtain a maximum impact inflation differential of about 0.3 percentage points when  $\theta_c = 11$  and  $\theta_c^* = 33$ .

## 4.2 The Role of Financial Frictions

In a standard New Keynesian model inflation drops after a technology shock (Gali, 2008).<sup>14</sup> The introduction of borrowers attenuates the decline of inflation (Figure 2). Since borrowers are more impatient than savers, they react to a technology shock by increasing their demand for consumption goods and housing services relatively strongly. This reaction is amplified by the induced rise in house prices, which, everything else equal, loosens the credit constraint and strengthens the incentive to borrow further. This is a version of the so called "*financial accelerator effect*". Accordingly, the shift of aggregate demand in response to the technology shock is more pronounced, which mitigates the decline of inflation.<sup>15</sup>

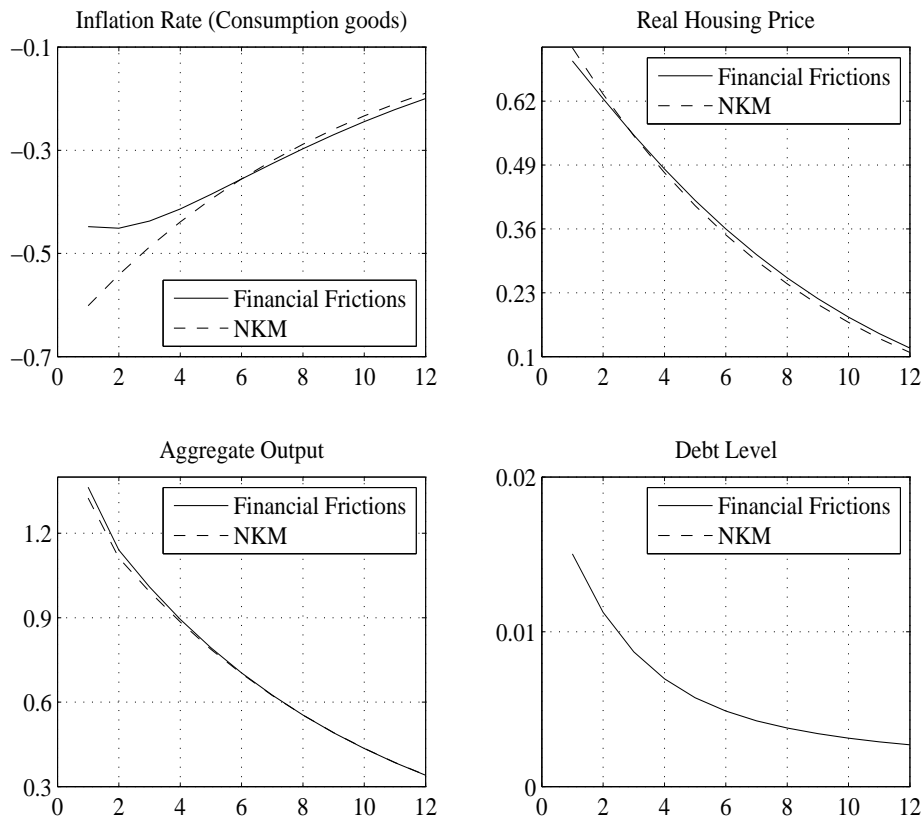
The financial accelerator effect also enriches the transmission of monetary policy shocks to the real economy. As revealed by Figure 3, the fall of inflation is reinforced after a monetary policy contraction. In this case current and expected inflation fall. This induces a negative income effect on indebted households since the real service cost of nominal debt rises. Furthermore, the monetary shock also affects the credit constraint: For any given level of the housing stock and expected house prices the drop in inflation tightens the borrowing constraint and at the same time reduces the marginal utility of further borrowing due to the higher future service cost of debt. All these effects reduce borrowers' consumption and housing demand and lead to a decrease in house prices. The latter, in turn, reinforces the negative effects on the credit constraint just described and hence, magnifies the drop in borrowers' consumption demand. If financial markets were frictionless, the economy would exhibit a weaker drop in inflation after a negative monetary shock since the negative effects on consumption demand operating *via* nominal debt and the credit constraint would be absent. It can be shown that the higher the fraction of borrowers, the more pronounced the negative effect of

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<sup>14</sup>Note that in our case the standard New Keynesian model is augmented by the presence of a housing sector.

<sup>15</sup>Note that borrowers benefit from higher wages, higher house prices and lower nominal interest rates while suffering an increase in real debt burden due to the lower inflation rate (negative wealth effect). However, the latter only partly offsets the positive effect of increased wages, house prices and lower nominal interest rates.

Figure 2: Impulse Responses to a Common Technology Shock  
 – The Role of Financial Frictions –



*Notes:* Comparison between the standard New Keynesian model (NKM) with housing sector and the model with financial frictions, where  $1 - \omega = 1 - \omega^* = 0.4$  and  $1 - \xi = 1 - \xi^* = 0.75$ . Inflation rate: annualized, deviations from steady state are measured in percentage points. Remaining variables: deviations from steady state are measured in percent.

a monetary tightening on current inflation.<sup>16</sup>

## 4.3 Asymmetric Countries with Financial Frictions

### 4.3.1 Inflation Differentials and Different Shares of Borrowers

When countries in a monetary union are asymmetric with respect to the share of borrowers, common shocks can trigger sizable inflation dispersion. Differences in the share of borrowers result from variations in  $1 - \omega^*$ . The remaining parameters, in particular  $1 - \omega$  and the loan-to-value ratios are set according to the benchmark calibration.

**Monetary policy shock** Figure 4 summarizes the responses of the variables to a restrictive monetary policy shock. As expected, the financial accelerator effect is stronger in the country characterized by a larger fraction of borrowers (the foreign country in this case), inducing a larger drop in borrowers' consumption and housing demand. Accordingly the downturn triggered by the monetary contraction is more severe and is accompanied by a larger inflation decrease in Foreign than in Home. The differential in consumer price inflation is significant and persists for about two quarters.

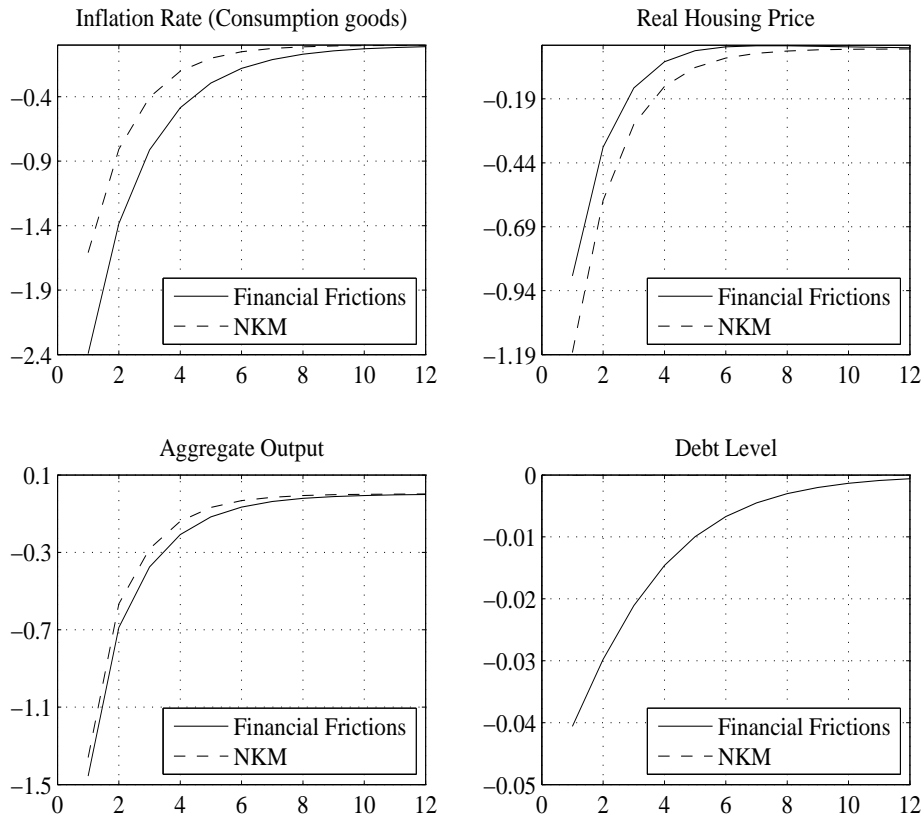
As revealed by Figure 5 the empirically plausible range of cross country asymmetries regarding the share of indebted households leads to substantial inflation differentials of similar magnitude as those implied by differences in the degree of price stickiness. For example, if borrowers constitute a fraction of 40% in Home and 20% in Foreign then the inflation differential on impact amounts to 0.21 percentage points. Shares of borrowers of 40% in Home and 60% in Foreign induce an even larger inflation differential equal to about 0.45 percentage points. For comparison, in the case without financial frictions, if the Calvo parameters are equal to 0.75 in Home and 0.65 in Foreign (the largest difference considered), the resulting impact inflation differential is about 0.42 percentage points (see also Figure 1).

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<sup>16</sup>The simulation results are available upon request.

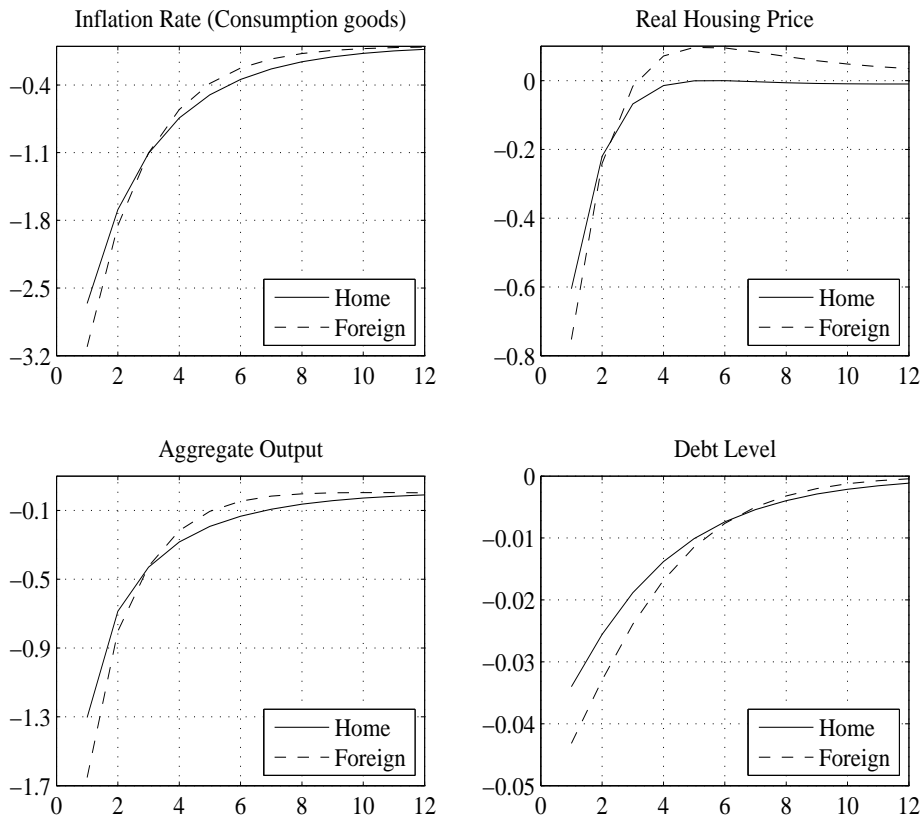


Figure 3: Impulse Responses to a Common Monetary Policy Shock  
 – The Role of Financial Frictions –



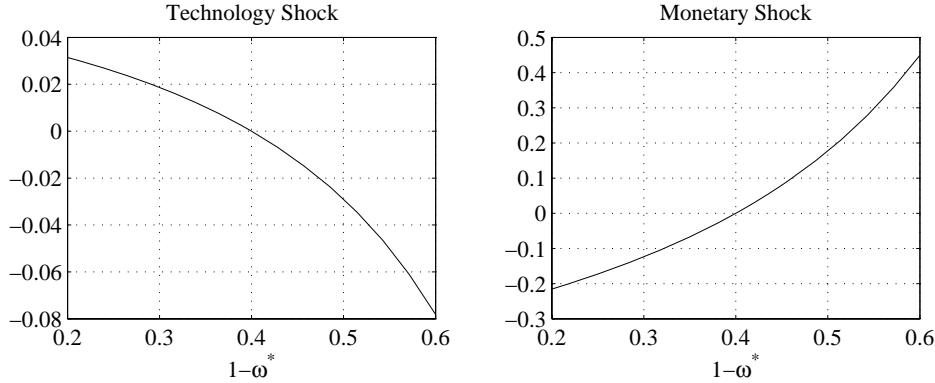
*Notes:* Comparison between the standard New Keynesian model (NKM) with housing sector and the model with financial frictions, where  $1 - \omega = 1 - \omega^* = 0.4$  and  $1 - \xi = 1 - \xi^* = 0.75$ . Inflation rate: annualized, deviations from steady state are measured in percentage points. Remaining variables: deviations from steady state are measured in percent.

Figure 4: Impulse Responses to a Common Monetary Policy Shock  
 – Heterogeneous Shares of Borrowers –



*Notes:* Model with financial frictions and country-specific shares of borrowers:  $1 - \omega = 0.4$ ,  $1 - \omega^* = 0.6$  and  $1 - \xi = 1 - \xi^* = 0.75$ . Inflation rate: annualized, deviations from steady state are measured in percentage points. Remaining variables: deviations from steady state are measured in percent.

Figure 5: Impact Inflation Differential:  $\pi_c - \pi_c^*$



*Notes:* Model with financial frictions and heterogeneity with respect to: the share of borrowers ( $1 - \omega$  is set to its baseline value of 0.4). Impact differentials between annualized inflation rates measured in percentage points.

**Technology shock** Similar conclusions can be drawn if technology shocks are the main source of cyclical fluctuations (see Figure 5). The impact inflation differential found in a monetary union characterized by  $1 - \omega = 0.4$  and  $1 - \omega^* = 0.6$  is 0.08 percentage points while the combination  $1 - \omega = 0.4$  and  $1 - \omega^* = 0.2$  implies that inflation rates differ by about 0.03 percentage points on impact. For comparison, the largest differential implied by asymmetries in the Calvo parameters amounts to about 0.05 percentage points which corresponds to the case  $\alpha_c = 0.75$  and  $\alpha_c^* = 0.81$ .

For both countries, Figure 6 displays the responses of the variables to a symmetric technology shock. As explained above, the increase in house prices and the drop in inflation loosen borrowers' credit constraint and strengthen their incentive to increase consumption demand. The resulting positive pressure on consumption goods prices weakens the negative impact reaction of the inflation rate. This effect is more pronounced in the country with a higher share of indebted households where the increase in consumption demand turns out to be larger. For high enough cross-country heterogeneity with respect to the borrowers' share productivity disturbances do not only lead to quantitative but also to substantial qualitative inflation differentials: for example, if the fraction of indebted house-

holds amounts to 20% in Home and 80% in Foreign, a positive technology shock triggers a temporary increase of Home inflation while Foreign inflation falls. A higher fraction of borrowers also implies a smaller increase in housing investment: Since there is a larger increase in relative house prices, savers become relatively more reluctant to increase their housing stock (see Figure 6) .

### 4.3.2 Inflation Differentials and Different Loan–To–Value Ratios

A second potential source of cross–country heterogeneity in the Euro Area are asymmetries in the loan–to–value ratios. Anything else given, a higher loan–to–value ratio increases the sensitivity of borrowing and thus, of borrowers’ demand for consumption goods to changes in relative house prices, the inflation rate and the nominal interest rate and hence, contributes to strengthening the financial accelerator effect.<sup>17</sup> Differences in the loan–to–value ratios result from variations in  $1-\xi^*$ . The remaining parameters, in particular  $1-\xi$  and the shares of borrowers are set according to the benchmark calibration.

**Monetary policy shock** A higher loan–to–value ratio in Home magnifies the financial accelerator effect operating via the credit constraint and leads to a larger

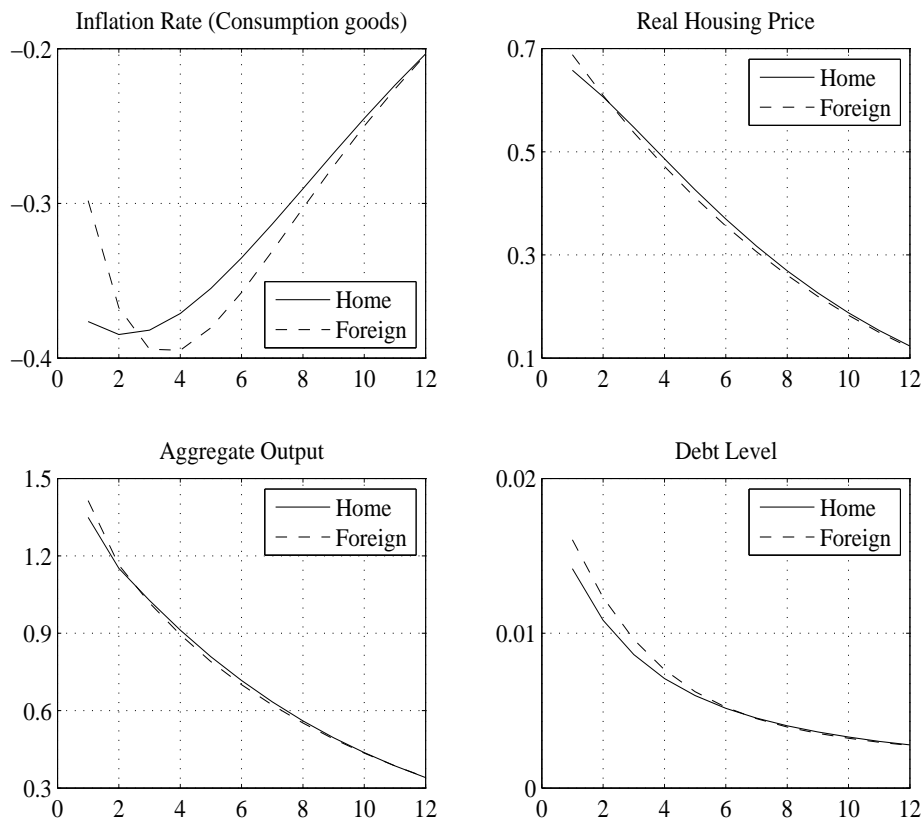
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<sup>17</sup> The borrower’s shadow value of an additional unit of housing,  $\Psi_t''$ , is given by:

$$\begin{aligned}\Psi_t'' &= U_{D,t}'' + (1-\xi)(1-\delta)\varphi_t q_t E_t \pi_{d,t+1} + \beta(1-\delta)E_t \Psi_{t+1}'' \\ \Leftrightarrow \Psi_t'' &= U_{D,t}'' + (1-\xi)(1-\delta)\varphi_t E_t q_{t+1} \pi_{c,t+1} + \beta(1-\delta)E_t \Psi_{t+1}'' \\ \Rightarrow q_t U_{C,t}'' = \Psi_t'' &= E_t \sum_{i=0}^{\infty} \beta^i (1-\delta)^i (U_{D,t+i}'' + (1-\xi)(1-\delta)\varphi_{t+i} q_{t+1+i} \pi_{c,t+1+i}),\end{aligned}$$

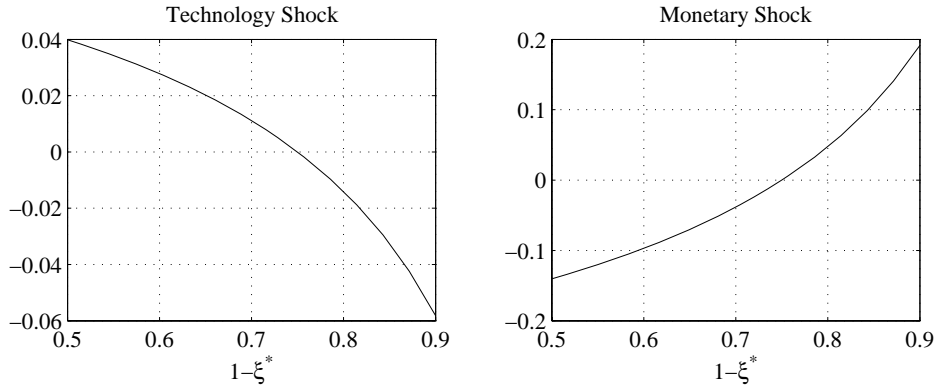
where  $U_{C,t}''$  ( $U_{D,t}''$ ) denotes the marginal utility of consumption (the housing stock) and  $\varphi_t$  represents the Lagrangean multiplier corresponding to the credit constraint. According to the last equation,  $\Psi_t''$  depends on the entire future path of the marginal utilities derived from the additional housing unit acquired in period  $t$ . While  $U_{D,t+i}''$  measures the direct effect on the borrower’s utility in  $t+i$  stemming from the increase in the housing stock, the term  $(1-\xi)(1-\delta)\varphi_{t+i} E_t q_{t+1+i} \pi_{c,t+1+i}$  reflects the additional utility derived by using the new house as a collateral. A higher loan–to–value ratio,  $1-\xi$ , makes  $\Psi_t''$  and thus, the marginal utility of consumption,  $U_{C,t}''$ , more sensitive to changes in  $\varphi_t$ ,  $E_t(q_{t+1}/q_t)$  and  $E_t \pi_{c,t+1}$ .

Figure 6: Impulse responses to a Common Technology Shock  
 – Heterogeneous Shares of Borrowers –



*Notes:* Model with financial frictions and country-specific shares of borrowers:  $1 - \omega = 0.4$ ,  $1 - \omega^* = 0.6$  and  $1 - \xi = 1 - \xi^* = 0.75$ . Inflation rate: annualized, deviations from steady state are measured in percentage points. Remaining variables: deviations from steady state are measured in percent.

Figure 7: Impact Inflation Differential:  $\pi_c - \pi_c^*$

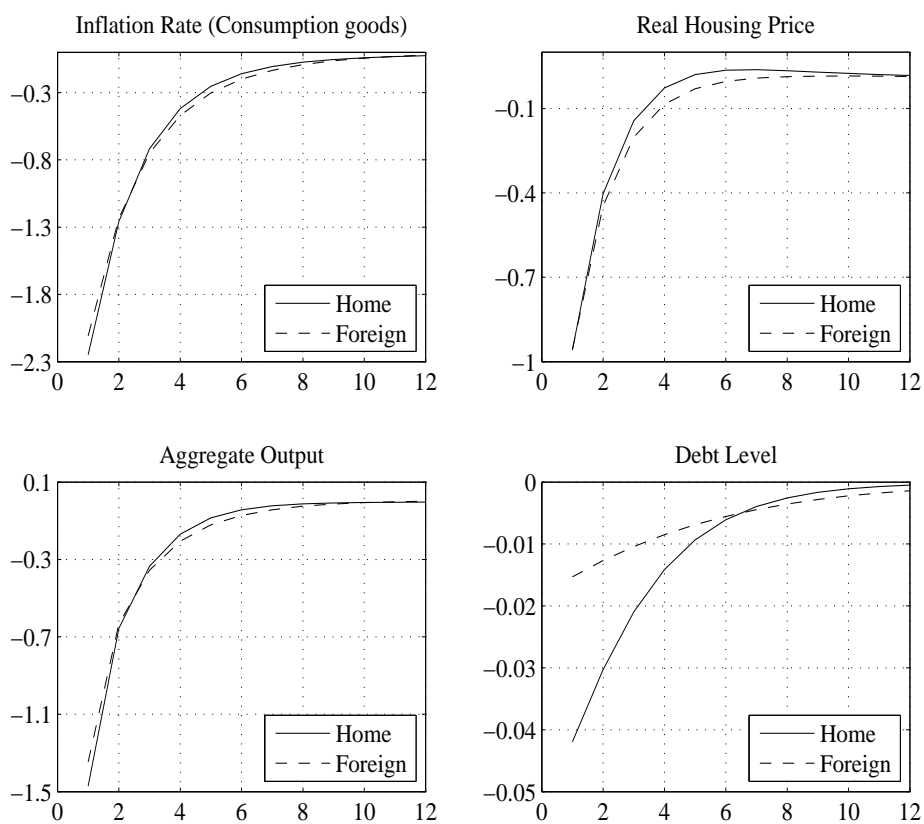


*Notes:* Model with financial frictions and heterogeneity with respect to the loan-to-value ratio ( $1-\xi$  is set to its baseline value of 0.75). Impact differentials between annualized inflation rates measured in percentage points.

drop of inflation and output in the face of a monetary contraction (see Figure 8). However, as Figure 7 shows, the empirically relevant range of cross-country heterogeneity in the loan-to-value ratios induces inflation differentials of more limited magnitude than those resulting from asymmetries in the fraction of borrowers. Thus, cyclical inflation dispersion in a monetary union can to a lesser extent be explained by heterogenous loan-to-value ratios. However, given that the proportion of households holding debt appears to be positively correlated to the loan-to-value ratio (see Table 2), the inflation differentials generated by a simultaneous heterogeneity in both, the fraction of indebted households and the loan-to-value ratio, can be substantially larger than that induced by cross country differences in price rigidity or the degree of competitiveness.

**Technology shock** As illustrated by Figure 9, a positive technology shock leads to a larger inflation decline in the country with the lower loan-to-value ratio and thus, the weaker financial accelerator effect (the foreign country in this case). The particular asymmetry in the loan-to-value ratios assumed,  $1-\xi = 0.75$  and  $1-\xi^* = 0.5$  implies a significant short-run inflation differential amounting to about 0.1 percentage points. However, Figure 7 reveals that the impact inflation

Figure 8: Impulse Responses to a Monetary Shock  
 – Heterogeneous Loan-to-value Ratios –

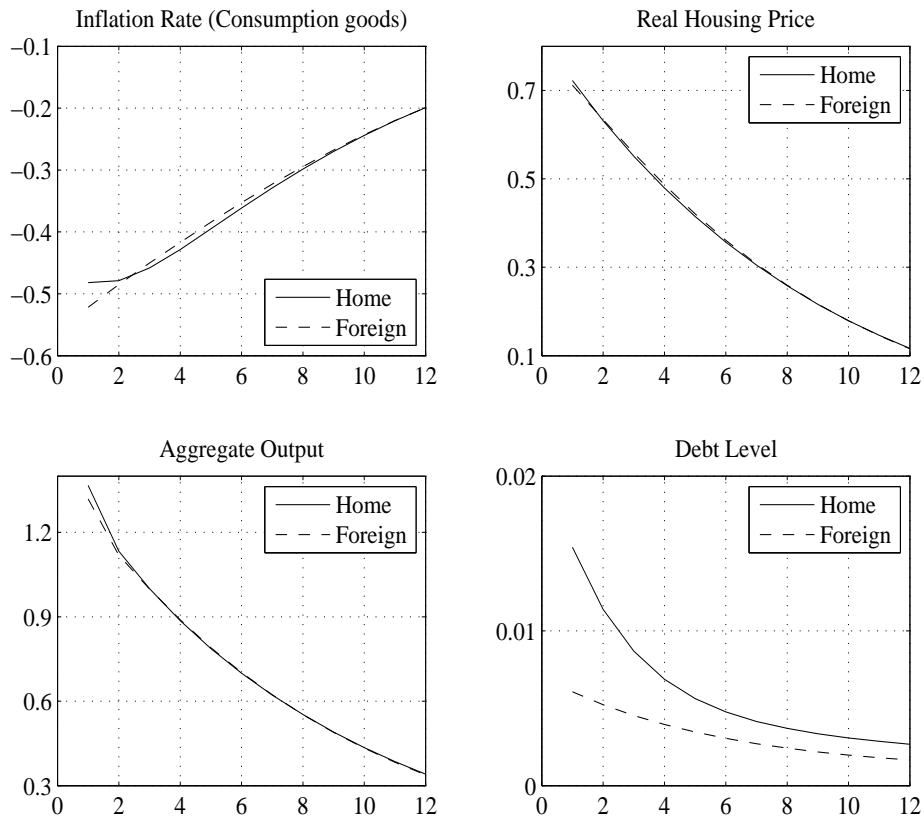


*Notes:* Model with financial frictions and country-specific loan-to-value ratios:  $1 - \xi = 0.75$ ,  $1 - \xi^* = 0.5$  and  $1 - \omega = 1 - \omega^* = 0.4$ . Inflation rate: annualized, deviations from steady state are measured in percentage points. Remaining variables: deviations from steady state are measured in percent.

differential resulting from an empirically plausible degree of heterogeneity in the loan-to-value ratio is smaller than the impact inflation differential resulting from cross-country differences in the share of borrowers.



Figure 9: Impulse Responses to a Common Technology Shock  
 – Heterogeneous Loan-to-value Ratios –



*Notes:* Model with financial frictions and country-specific loan-to-value ratios:  $1 - \xi = 0.75$ ,  $1 - \xi^* = 0.5$  and  $1 - \omega = 1 - \omega^* = 0.4$ . Inflation rate: annualized, deviations from steady state are measured in percentage points. Remaining variables: deviations from steady state are measured in percent.

## 5 Conclusion

We employ a New Keynesian DSGE model for a monetary union to analyze whether cyclical inflation differentials can be explained by cross-country differences concerning the characteristics of financial markets. The model is inspired by Monacelli (2009), as we consider two types of households, namely savers and borrowers, which differ from each other in the degree of patience, and two types of firms, which produce differentiated goods in two sectors, namely a consumption goods sector and a housing sector. Since borrowers are assumed to face a credit constraint, we explicitly account for a financial accelerator mechanism.

Our results suggest that empirically plausible degrees of heterogeneity with respect to two important credit market characteristics – namely the fraction of borrowers and to a lesser extent the loan-to-value ratio – generate inflation differentials that are similar to those implied by structural differences with respect to price inertia and the degree of competitiveness. Thus, our work can be seen as complementary to the work of Andres et al. (2008) and Angeloni and Ehrmann (2007). The main finding of our paper is that the characteristics of financial markets should be seen as an alternative explanation for the observable inflation dispersion in the EMU. In particular, we observe that in the case of monetary shocks the response of inflation is more pronounced in member states with a larger share of borrowers and/or a higher loan-to-value ratio. If a common technology shock hits the monetary union, the reverse is true.

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# Appendix

## A Summary of Model Equations

### A.1 Technology

For consumption good producers the production functions are:

$$Y_{ct} = \exp(\zeta_t) N_{ct} \left( (1 - \alpha_c) \tilde{p}_{Ht}^{-\theta} + \alpha_c \left( \frac{1}{\pi_{Ht}} \right)^{-\theta} \right)^{-1} \quad (\text{A.1})$$

$$Y_{ct}^* = \exp(\zeta_t) N_{ct}^* \left( (1 - \alpha_c^*) \tilde{p}_{ft}^{-\theta^*} + \alpha_c^* \left( \frac{1}{\pi_{ft}^*} \right)^{-\theta^*} \right)^{-1} \quad (\text{A.2})$$

Similarly, the production functions of housing good producers are:

$$Y_{dt} = \exp(\zeta_t) N_{dt} \left( (1 - \alpha_d) \tilde{p}_{dt}^{-\theta} + \alpha_d \left( \frac{1}{\pi_{dt}} \right)^{-\theta} \right)^{-1} \quad (\text{A.3})$$

$$Y_{dt}^* = \exp(\zeta_t) N_{dt}^* \left( (1 - \alpha_d^*) \tilde{p}_{dt}^{-\theta^*} + \alpha_d^* \left( \frac{1}{\pi_{dt}^*} \right)^{-\theta^*} \right)^{-1} \quad (\text{A.4})$$

### A.2 Demand Functions

For savers in country H and F the set of demand functions is:

$$C'_{Ht} = \nu C'_t (\nu + (1 - \nu) \tau_t^{1-b})^{\frac{b}{1-b}} \quad (\text{A.5})$$

$$C'_{Ft} = (1 - \nu) C'_t (\nu \tau_t^{b-1} + 1 - \nu)^{\frac{b}{1-b}} \quad (\text{A.6})$$

$$C'^*_{Ft} = \nu^* C'^*_t ((1 - \nu^*) \tau_t^{b-1} + \nu^*)^{\frac{b}{1-b}} \quad (\text{A.7})$$

$$C'^*_{Ht} = (1 - \nu^*) C'^*_t (1 - \nu^* + \nu^* \tau_t^{1-b})^{\frac{b}{1-b}} \quad (\text{A.8})$$

where  $\tau$  denotes the terms of trade, which are defined as:

$$\tau_t = \frac{P_{Ft}}{P_{Ht}},$$

such that  $\tau_t^* = 1/\tau_t$ .

For borrowers in country H and F the set of demand functions is:

$$C''_{Ht} = \nu C''_t (\nu + (1 - \nu) \tau_t^{1-b})^{\frac{b}{1-b}} \quad (\text{A.9})$$

$$C''_{Ft} = (1 - \nu) C''_t (\nu \tau_t^{b-1} + 1 - \nu)^{\frac{b}{1-b}} \quad (\text{A.10})$$

$$C''_{Ft}^* = \nu^* C''_t^* ((1 - \nu^*) \tau_t^{b-1} + \nu^*)^{\frac{b}{1-b}} \quad (\text{A.11})$$

$$C''_{Ht}^* = (1 - \nu^*) C''_t^* (1 - \nu^* + \nu^* \tau_t^{1-b})^{\frac{b}{1-b}} \quad (\text{A.12})$$

Notice that the law of one price is assumed to hold, such that:  $P_{Ht} = P_{Ht}^*$  and  $P_{Ft}^* = P_{Ft}$ .

### A.3 Savers in Country H

$$C'_t = C'_{t+1} \left[ \beta \frac{R_{Ht}}{\pi_{ct+1}} \right]^{-1} \quad (\text{A.13})$$

$$q_t = \frac{1 - \gamma}{\gamma} \frac{C'_t}{D'_t} + \beta(1 - \delta) \left[ q_{t+1} \frac{C'_t}{C'_{t+1}} \right] \quad (\text{A.14})$$

$$\varphi'_c (N'_{ct})^\eta C'_t = \gamma w_{ct} \quad (\text{A.15})$$

$$\varphi'_d (N'_{dt})^\eta C'_t = \gamma w_{dt} \quad (\text{A.16})$$

$$R_{Ht} = \frac{R_t}{1 + \phi d'_t} \quad (\text{A.17})$$



#### A.4 Savers in Country F

$$C_t^{I*} = C_{t+1}^{I*} \left[ \beta^* \frac{R_{Ft}}{\pi_{ct+1}^*} \right]^{-1} \quad (\text{A.18})$$

$$q_t^* = \frac{1 - \gamma^*}{\gamma^*} \frac{C_t^{I*}}{D_t^{I*}} + \beta^*(1 - \delta^*) \left[ q_{t+1}^* \frac{C_t^{I*}}{C_{t+1}^{I*}} \right] \quad (\text{A.19})$$

$$\varphi_c^{I*} (N_{ct}^{I*})^{\eta^*} C_t^{I*} = \gamma^* w_{ct}^* \quad (\text{A.20})$$

$$\varphi_d^{I*} (N_{dt}^{I*})^{\eta^*} C_t^{I*} = \gamma^* w_{dt}^* \quad (\text{A.21})$$

$$R_{Ft} = \frac{R_t}{1 + \phi^* a_t^{I*}} \quad (\text{A.22})$$

#### A.5 Borrowers in Country H

$$C_t'' + q_t [D_t'' - (1 - \delta) D_{t-1}''] + \frac{R_{Ht-1}}{\pi_{ct}} b_{t-1}'' = w_{ct} N_{ct}'' + w_{dt} N_{dt}'' + b_t'' \quad (\text{A.23})$$

$$R_{Ht} b_t'' = (1 - \chi) q_{t+1} \pi_{ct+1} (1 - \delta) D_t'' \quad (\text{A.24})$$

$$\begin{aligned} q_t &= \frac{1 - \gamma}{\gamma} \frac{C_t''}{D_t''} + (1 - \chi)(1 - \delta) \psi_t q_t \pi_{dt+1} \\ &\quad + v(1 - \delta) \left[ q_{t+1} \frac{C_t''}{C_{t+1}''} \right] \end{aligned} \quad (\text{A.25})$$

$$\varphi_c'' (N_{ct}'')^{\eta} C_t'' = \gamma w_{ct} \quad (\text{A.26})$$

$$\varphi_d'' (N_{dt}'')^{\eta} C_t'' = \gamma w_{dt} \quad (\text{A.27})$$

$$\psi_t R_{Ht} = 1 - v \left[ \frac{C_t''}{C_{t+1}''} \frac{R_{Ht}}{\pi_{ct+1}} \right] \quad (\text{A.28})$$

## A.6 Borrowers in Country F

$$C_t^{''*} + q_t^*[D_t^{''*} - (1 - \delta^*)D_{t-1}^{''*}] + \frac{R_{Ft-1}}{\pi_{ct}^*}b_{t-1}^{''*} = w_{ct}^*N_{ct}^{''*} + w_{dt}^*N_{dt}^{''*} + b_t^{''*} \quad (\text{A.29})$$

$$R_{Ft}b_t^{''*} = (1 - \chi^*)q_{t+1}^*\pi_{ct+1}^*(1 - \delta^*)D_t^{''*} \quad (\text{A.30})$$

$$\begin{aligned} q_t^* &= \frac{1 - \gamma^*}{\gamma^*} \frac{C_t^{''*}}{D_t^{''*}} + (1 - \chi^*)(1 - \delta^*)\psi_t^*q_t^*\pi_{dt+1}^* \\ &\quad + v^*(1 - \delta^*) \left[ q_{t+1}^* \frac{C_t^{''*}}{C_{t+1}^{''*}} \right] \end{aligned} \quad (\text{A.31})$$

$$\varphi_c^{''*}(N_{ct}^{''*})^{\eta^*} C_t^{''*} = \gamma^* w_{ct}^* \quad (\text{A.32})$$

$$\varphi_d^{''*}(N_{dt}^{''*})^{\eta^*} C_t^{''*} = \gamma^* w_{dt}^* \quad (\text{A.33})$$

$$\psi_t^* R_{Ft} = 1 - v^* \left[ \frac{C_t^{''*}}{C_{t+1}^{''*}} \frac{R_{Ft}}{\pi_{ct+1}^*} \right] \quad (\text{A.34})$$

## A.7 Aggregate Consumption

$$C_{Ht} = \omega C'_{Ht} + (1 - \omega) C''_{Ht} \quad (\text{A.35})$$

$$C_{Ft}^* = \omega^* C'_{Ft} + (1 - \omega^*) C''_{Ft} \quad (\text{A.36})$$

$$C_{Ft} = \omega C'_{Ft} + (1 - \omega) C''_{Ft} \quad (\text{A.37})$$

$$C_{Ht}^* = \omega^* C'_{Ht} + (1 - \omega^*) C''_{Ht} \quad (\text{A.38})$$

$$C_t = n(\nu + (1 - \nu)\tau_t^{1-b})^{\frac{1}{b-1}} C_{Ht} + n(\nu\tau_t^{b-1} + 1 - \nu)^{\frac{1}{b-1}} C_{Ft} \quad (\text{A.39})$$

$$C_t^* = (1 - n)((1 - \nu^*)\tau_t^{b-1} + \nu^*)^{\frac{1}{b-1}} C_{Ft}^* + (1 - n)(1 - \nu^* + \nu^*\tau_t^{1-b})^{\frac{1}{b-1}} C_{Ht}^* \quad (\text{A.40})$$

## A.8 Market Clearing Conditions

### Market for Consumption Goods

$$Y_{ct} = nC_{Ht} + (1 - n)C_{Ht}^* + n\omega\frac{\phi}{2}a_t'^2(\nu + (1 - \nu)\tau_t^{1-b})^{\frac{1}{1-b}} \quad (\text{A.41})$$

$$Y_{ct}^* = (1 - n)C_{Ft}^* + nC_{Ft} + (1 - n)\omega^*\frac{\phi^*}{2}a_t'^{*2}((1 - \nu^*)\tau_t^{b-1} + \nu^*)^{\frac{1}{1-b}} \quad (\text{A.42})$$

### Market for Housing Services

$$Y_{dt} = n[\omega(D_t' - (1 - \delta)D_{t-1}') + (1 - \omega)(D_t'' - (1 - \delta)D_{t-1}'')] \quad (\text{A.43})$$

$$Y_{dt}^* = (1 - n)[\omega^*(D_t'^* - (1 - \delta^*)D_{t-1}'^*) + (1 - \omega^*)(D_t''^* - (1 - \delta^*)D_{t-1}''^*)] \quad (\text{A.44})$$

### International and National Debt Market

$$n\omega a_t' + (1 - n)\omega^* a_t'^* \left( \frac{\nu + (1 - \nu)\tau_t^{1-b}}{1 - \nu^* + \nu^*\tau_t^{1-b}} \right)^{\frac{1}{1-b}} = 0 \quad (\text{A.45})$$

$$\omega b_t' + (1 - \omega)b_t'' = 0$$

$$\omega^* b_t'^* + (1 - \omega^*)b_t''^* = 0$$

## Labor Markets

$$N_t = N_{ct} + N_{dt} \quad (\text{A.46})$$

$$N_{ct} = n[\omega N'_{ct} + (1 - \omega)N''_{ct}] \quad (\text{A.47})$$

$$N_{dt} = n[\omega N'_{dt} + (1 - \omega)N''_{dt}] \quad (\text{A.48})$$

$$N_t^* = N_{ct}^* + N_{dt}^* \quad (\text{A.49})$$

$$N_{ct}^* = (1 - n)[\omega^* N'^*_{ct} + (1 - \omega^*)N''^*_{ct}] \quad (\text{A.50})$$

$$N_{dt}^* = (1 - n)[\omega^* N'^*_{dt} + (1 - \omega^*)N''^*_{dt}] \quad (\text{A.51})$$

## Net Foreign Assets

$$n\omega a'_t = n\omega \frac{R_{t-1}}{\pi_{ct}} a'_{t-1} + (1 - n)(\nu + (1 - \nu)\tau_t^{1-b})^{\frac{1}{b-1}} C_{Ht}^* - n(\nu\tau_t^{b-1} + 1 - \nu)^{\frac{1}{b-1}} C_{Ft}^* \quad (\text{A.52})$$

## A.9 Evolution of Relative Prices

### Market for Intermediate Consumption Goods

$$\tilde{p}_{Ht} = \frac{\theta_c}{\theta_c - 1} (\nu + (1 - \nu)\tau_t^{1-b})^{\frac{1}{1-b}} \frac{\Delta^z_{Ht}}{\Delta^n_{Ht}} \quad (\text{A.53})$$

$$\Delta^z_{Ht} = Y_{ct} \vartheta_{ct} + \alpha_c \beta \frac{C'_t}{C'_{t+1}} \pi_{Ht+1}^{\theta_c} \Delta^z_{Ht+1} \quad (\text{A.54})$$

$$\Delta^n_{Ht} = Y_{ct} + \alpha_c \beta \frac{C'_t}{C'_{t+1}} \frac{\pi_{Ht+1}^{\theta_c}}{\pi_{ct+1}} \Delta^n_{Ht+1} \quad (\text{A.55})$$

$$1 = (1 - \alpha_c) \tilde{p}_{Ht}^{1-\theta_c} + \alpha_c \left( \frac{1}{\pi_{Ht}} \right)^{1-\theta_c} \quad (\text{A.56})$$

$$\tilde{p}_{Ft}^* = \frac{\theta_c^*}{\theta_c^* - 1} ((1 - \nu^*) \tau_t^{b-1} + \nu^*)^{\frac{1}{1-b}} \frac{\Delta_{Ft}^{z*}}{\Delta_{Ft}^{n*}} \quad (\text{A.57})$$

$$\Delta_{Ft}^{z*} = Y_{ct}^* \vartheta_{ct}^* + \alpha_c^* \beta^* \frac{C_t'^*}{C_{t+1}'^*} (\pi_{Ft+1}^*)^{\theta_c^*} \Delta_{Ft+1}^{z*} \quad (\text{A.58})$$

$$\Delta_{Ft}^{n*} = Y_{ct}^* + \alpha_c^* \beta^* \frac{C_t'^*}{C_{t+1}'^*} \frac{(\pi_{Ft+1}^*)^{\theta_c^*}}{\pi_{ct+1}^*} \Delta_{Ft+1}^{n*} \quad (\text{A.59})$$

$$1 = (1 - \alpha_c^*) (\tilde{p}_{Ft}^*)^{1-\theta_c^*} + \alpha_c^* \left( \frac{1}{\pi_{Ft}^*} \right)^{1-\theta_c^*} \quad (\text{A.60})$$

### Market for Housing Services

$$\tilde{p}_{dt} = \frac{\theta_d}{\theta_d - 1} q_t^{-1} \frac{\Delta_{dt}^z}{\Delta_{dt}^n} \quad (\text{A.61})$$

$$\Delta_{dt}^z = Y_{dt} \vartheta_{dt} + \alpha_d \beta \frac{C_t'}{C_{t+1}'} \pi_{dt+1}^\theta \Delta_{dt+1}^z \quad (\text{A.62})$$

$$\Delta_{dt}^n = Y_{dt} + \alpha_d \beta \frac{C_t'}{C_{t+1}'} \frac{\pi_{dt+1}^{\theta_d}}{\pi_{ct+1}} \Delta_{dt+1}^n \quad (\text{A.63})$$

$$1 = (1 - \alpha_d) \tilde{p}_{dt}^{1-\theta_d} + \alpha_d \left( \frac{1}{\pi_{dt}} \right)^{1-\theta_d} \quad (\text{A.64})$$

$$\tilde{p}_{dt}^* = \frac{\theta_d^*}{\theta_d^* - 1} (q_t^*)^{-1} \frac{\Delta_{dt}^{z*}}{\Delta_{dt}^{n*}} \quad (\text{A.65})$$

$$\Delta_{dt}^{z*} = Y_{dt}^* \vartheta_{dt}^* + \alpha_d^* \beta^* \frac{C_t'^*}{C_{t+1}'^*} (\pi_{dt+1}^*)^{\theta_d^*} \Delta_{dt+1}^{z*} \quad (\text{A.66})$$

$$\Delta_{dt}^{n*} = Y_{dt}^* + \alpha_d^* \beta^* \frac{C_t'^*}{C_{t+1}'^*} \frac{(\pi_{dt+1}^*)^{\theta_d^*}}{\pi_{ct+1}^*} \Delta_{dt+1}^{n*} \quad (\text{A.67})$$

$$1 = (1 - \alpha_d^*) (\tilde{p}_{dt}^*)^{1-\theta_d^*} + \alpha_d^* \left( \frac{1}{\pi_{dt}^*} \right)^{1-\theta_d^*} \quad (\text{A.68})$$

### Real Marginal Costs

$$\vartheta_{ct} = \frac{w_{ct}}{\exp(\zeta_t)} \quad (\text{A.69})$$

$$\vartheta_{dt} = \frac{w_{dt}}{\exp(\zeta_t)} \quad (\text{A.70})$$

$$\vartheta_{ct}^* = \frac{w_{ct}^*}{\exp(\zeta_t)} \quad (\text{A.71})$$

$$\vartheta_{dt}^* = \frac{w_{dt}^*}{\exp(\zeta_t)} \quad (\text{A.72})$$

### Consumer Price Inflation

$$\pi_{ct} = \frac{\nu + (1 - \nu)\tau_t^{1-b}}{\nu\pi_{Ht}^{b-1} + (1 - \nu)\tau_t^{1-b}\pi_{Ft}^{b-1}} \quad (\text{A.73})$$

$$\pi_{ct}^* = \frac{1 - \nu^* + \nu^*\tau_t^{1-b}}{(1 - \nu^*)\pi_{Ht}^{b-1} + \nu^*\tau_t^{1-b}\pi_{Ft}^{b-1}} \quad (\text{A.74})$$

### Real House Prices and Terms of Trade

$$q_t = q_{t-1} \frac{\pi_{dt}}{\pi_{ct}} \quad (\text{A.75})$$

$$q_t^* = q_{t-1}^* \frac{\pi_{dt}^*}{\pi_{ct}^*} \quad (\text{A.76})$$

$$\tau_t = \tau_{t-1} \frac{\pi_{Ft}^*}{\pi_{Ht}} \quad (\text{A.77})$$

## A.10 Aggregate Output

$$Y_t = \tilde{p}_{yt}^{-1} (\nu + (1 - \nu)\tau_t^{1-b})^{\frac{1}{b-1}} Y_{ct} + \tilde{p}_{yt}^{-1} q_t Y_{dt} \quad (\text{A.78})$$

$$\tilde{p}_{yt} \equiv \frac{P_{yt}}{P_{ct}} = \frac{(\nu + (1 - \nu)\tau_t^{1-b})^{\frac{1}{b-1}} Y_{ct}}{(\nu + (1 - \nu)\tau_t^{1-b})^{\frac{1}{b-1}} Y_{ct} + q_t Y_{dt}} (\nu + (1 - \nu)\tau_t^{1-b})^{\frac{1}{b-1}} +$$

$$+ \frac{q_t Y_{dt}}{(\nu + (1 - \nu)\tau_t^{1-b})^{\frac{1}{b-1}} Y_{ct} + q_t Y_{dt}} q_t$$

$$Y_t^* = (\tilde{p}_{yt}^*)^{-1} ((1 - \nu^*)\tau_t^{b-1} + \nu^*)^{\frac{1}{b-1}} Y_{ct}^* + (\tilde{p}_{yt}^*)^{-1} q_t^* Y_{dt}^* \quad (\text{A.80})$$

$$\tilde{p}_{yt}^* \equiv \frac{P_{yt}^*}{P_{ct}^*} = \frac{((1 - \nu^*)\tau_t^{b-1} + \nu^*)^{\frac{1}{b-1}} Y_{ct}^*}{((1 - \nu^*)\tau_t^{b-1} + \nu^*)^{\frac{1}{b-1}} Y_{ct}^* + q_t^* Y_{dt}^*} ((1 - \nu^*)\tau_t^{b-1} + \nu^*)^{\frac{1}{b-1}} +$$

$$+ \frac{q_t^* Y_{dt}^*}{((1 - \nu^*)\tau_t^{b-1} + \nu^*)^{\frac{1}{b-1}} Y_{ct}^* + q_t^* Y_{dt}^*} q_t^*$$

$$(\text{A.81})$$

## A.11 Area-wide Aggregates

Area-wide output is given by

$$Y_t^{EMU} = \kappa_{yt} Y_t + (1 - \kappa_{yt}) \frac{P_{ct}^*}{P_{ct}} Y_t^*, \quad (\text{A.82})$$

where

$$\kappa_{yt} = (\tilde{p}_{yt}^{EMU})^{-1} \tilde{p}_{yt}$$

and

$$\tilde{p}_{yt}^{EMU} \equiv \frac{P_{yt}^{EMU}}{P_{ct}} = \left( \frac{\tilde{p}_{yt} Y_t}{\tilde{p}_{yt} Y_t + \tilde{p}_{yt}^* \left( \frac{1 - \nu^* + \nu^* \tau_t^{1-b}}{\nu + (1 - \nu)\tau_t^{1-b}} \right)^{\frac{1}{1-b}}} \right) \tilde{p}_{yt} +$$

$$+ \left( \frac{\tilde{p}_{yt}^* \left( \frac{1 - \nu^* + \nu^* \tau_t^{1-b}}{\nu + (1 - \nu)\tau_t^{1-b}} \right)^{\frac{1}{1-b}} Y_t^*}{\tilde{p}_{yt} Y_t + \tilde{p}_{yt}^* \left( \frac{1 - \nu^* + \nu^* \tau_t^{1-b}}{\nu + (1 - \nu)\tau_t^{1-b}} \right)^{\frac{1}{1-b}} Y_t^*} \right) \tilde{p}_{yt}^* \left( \frac{1 - \nu^* + \nu^* \tau_t^{1-b}}{\nu + (1 - \nu)\tau_t^{1-b}} \right)^{\frac{1}{1-b}}.$$

$$(\text{A.83})$$

Notice that  $P_{ct}^*/P_{ct}$  can be written as:

$$\frac{P_{ct}^*}{P_{ct}} = \left( \frac{1 - \nu^* + \nu^* \tau_t^{1-b}}{\nu + (1 - \nu) \tau_t^{1-b}} \right)^{\frac{1}{1-b}}.$$

Area-wide consumption–goods inflation is given by:

$$\pi_{ct}^{EMU} = \kappa_{ct} \pi_{ct} + (1 - \kappa_{ct}) \frac{P_{ct-1}^*}{P_{ct-1}} \pi_{ct}^*,$$

where  $\kappa_{ct}$  is defined as:

$$\kappa_{ct} = \frac{1}{\tilde{p}_{ct}^{EMU}} \left[ \frac{C_t}{C_t + \left( \frac{1 - \nu^* + \nu^* \tau_t^{1-b}}{\nu + (1 - \nu) \tau_t^{1-b}} \right)^{\frac{1}{1-b}} C_t^*} \right]$$

and  $\tilde{p}_{ct}^{EMU}$  is given by:

$$\begin{aligned} \tilde{p}_{ct}^{EMU} \equiv \frac{P_{ct}^{EMU}}{P_{ct}} &= \frac{C_t}{C_t + \left( \frac{1 - \nu^* + \nu^* \tau_t^{1-b}}{\nu + (1 - \nu) \tau_t^{1-b}} \right)^{\frac{1}{1-b}} C_t^*} + \\ &+ \frac{C_t^*}{\left( \frac{1 - \nu^* + \nu^* \tau_t^{1-b}}{\nu + (1 - \nu) \tau_t^{1-b}} \right)^{\frac{1}{1-b}} C_t + C_t^*} \left( \frac{1 - \nu^* + \nu^* \tau_t^{1-b}}{\nu + (1 - \nu) \tau_t^{1-b}} \right)^{\frac{1}{1-b}}. \end{aligned} \tag{A.84}$$

## A.12 Monetary Policy

$$\frac{R_t}{R} = \left( \frac{\pi_{ct}^{EMU}}{\pi_c^{EMU}} \right)^{\varrho \pi} \exp(z_t) \tag{A.85}$$

## A.13 Shocks

$$z_t = \rho_z z_{t-1} + \epsilon_{zt} \tag{A.86}$$

$$\zeta_t = \rho_\zeta \zeta_{t-1} + \zeta_{ct} \tag{A.87}$$



## B Differentiated Types of Labor

If both sectors employ a homogeneous type of labor and at the same time prices in the housing sector are relatively flexible, then, industry-specific output levels will tend to co-move negatively after a monetary policy shock. This subsection provides some intuition about the reasons for this result as well as how the assumption of differentiated types of labor helps to solve this co-movement problem. For notational convenience, the exposition refers to a closed economy with homogeneous households, i.e. without financial frictions. However, the same reasoning – albeit slightly modified – holds in a economy populated by savers and borrowers.

The feature responsible for the negative co-movement between the two sectors in the case of perfect labor mobility across industries is the assumption that prices in the non-durable consumption sector are more sticky than it is the case in the housing sector. A monetary expansion leads to an increase in current consumption demand, prices and real wages. The latter results from an increase in marginal disutility of labor. Accordingly, the marginal utility of consumption  $U_{C,t} = \gamma C_t^{-1}$  falls. Furthermore, in equilibrium the marginal rate of substitution between purchasing an additional unit of housing and an additional consumption good should be equal to the relative house price:

$$\Psi_t = q_t U_{C,t}, \tag{B.1}$$

where  $\Psi_t$  denotes the shadow value of an additional investment in housing while  $q_t$  is its relative price. Since the housing stock is a non-durable good,  $\Psi_t$  does not equal its current marginal utility  $U_{D,t} = (1 - \gamma)D_t^{-1}$  but rather the expected

present value of current and future marginal utilities:<sup>18</sup>

$$\Psi_t = U_{D,t} + \beta(1 - \delta)E_t U_{D,t+1} + \beta^2(1 - \delta)^2 E_t U_{D,t+2} + \dots = E_t \sum_{i=0}^{\infty} \beta^i (1 - \delta)^i U_{D,t+i}.$$

Since the shadow value of housing investment depends on a stock rather than a flow on the one hand and on the entire future path of this stock on the other, relatively small changes in  $\Psi_t$  will have to be accommodated by relatively large swings in housing investment. According to equation (B.1) for a given  $q_t$  the drop in the marginal utility of consumption triggered by the monetary shock will cause a reduction in the desired shadow value of housing investment and thus, will push the demand for new housing units up. Indeed, exactly this will be the outcome if prices in both sectors were completely sticky or at least about equally sticky in the short run. In other words, if prices in the housing industry are sufficiently rigid relative to that of consumption goods then both sectors will tend to co-move positively.

Unfortunately, the prices of most durables, especially houses are quite flexible. Therefore the positive pressure on current labor demand and current nominal wages exerted by the monetary expansion translates into a relatively rapid acceleration of house price inflation and eventually into an increase in the relative price  $q_t$ . In other words, house producing firms pass a larger part of the nominal wage increase through to house prices. For sufficiently high degrees of price flexibility in the housing sector the increase in  $q_t$  more than compensates the fall in the marginal utility of consumption  $U_{C,t}$ . In such a case equation (B.1) implies that the shadow value of housing investment should rise and accordingly, housing production should contract. Hence, the equilibrium reaction to the monetary policy

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<sup>18</sup>The first order condition with respect to next period's stock of housing implies:

$$\Psi_t = U_{D,t} + \beta(1 - \delta)E_t \Psi_{t+1},$$

where  $U_{D,t}$  denotes the marginal utility of the stock in period  $t$ . Iterating this equation forwards and imposing the appropriate transversality condition yields:

$$\Psi_t = U_{D,t} + \beta(1 - \delta)E_t U_{D,t+1} + \beta^2(1 - \delta)^2 E_t U_{D,t+2} + \dots = E_t \sum_{i=0}^{\infty} \beta^i (1 - \delta)^i U_{D,t+i}.$$

shock will be associated with a negative co-movement between both sectors. In the extreme case of perfectly flexible house prices, the markup in the housing industry would be constant,  $\frac{W_t/P_{c,t}}{q_t} = \frac{\theta_d - 1}{\theta_d}$ . Then it would suffice to take a look at the first order condition for optimal labor supply in order to conclude that housing production will respond negatively to monetary shocks: the optimality condition for working hours can be written as

$$\varphi N_t^\eta = \lambda_t \frac{W_t}{P_{c,t}} = \frac{\Psi_t}{q_t} \frac{W_t}{P_{c,t}} = \Psi_t \frac{\theta_d - 1}{\theta_d}.$$

If the monetary expansion leads to an increase in working hours,  $N_t$ , then the shadow value  $\Psi_t$  should rise and thus, aggregate housing demand should decrease.

If both sectors employ heterogenous types of labor – as assumed in our model – the increase in consumption demand triggered by a monetary policy shock again induces a sharp increase of the nominal wage in the non-durable goods sector. However, the pressure on labor market costs only partly translates into higher wages in the housing industry. As a result, for any given level of price flexibility in the housing sector the increase in the relative price  $q_t$  tends to be weaker than in an economy with homogeneous labor markets. Therefore, it becomes more difficult for the two industries to move in opposite directions. This is easily seen by noting that, if house prices were perfectly flexible, then activity in the durable goods sector would be perfectly isolated from the rest of the economy and thus, from a monetary policy shock: The shadow price of housing investment and the corresponding stock evolve according to the following equations respectively:

$$\Psi_t = U_{D,t} + \beta(1 - \delta)E_t\Psi_{t+1}$$

$$D_t = \exp(\zeta_t)N_{d,t} + (1 - \delta)D_{t-1}.$$

Hence,  $\Psi_t$  is a function of current and expected future labor inputs in the durable goods industry. Let us denote this function by  $\Psi(N_{d,t-1}, N_{d,t}, N_{d,t+1}, \dots)$ . As a consequence, the optimality condition for hours supplied to the housing sector define a relationship between current, past and future  $N_{d,t}$ :

$$\varphi_d N_{d,t}^\eta = \frac{\theta_d - 1}{\theta_d} \Psi_t = \frac{\theta_d - 1}{\theta_d} \Psi(N_{d,t-1}, N_{d,t}, N_{d,t+1}, \dots).$$

The latter is a non-linear forward looking difference equation which determines the path of  $N_{d,t}$  independently of any other endogenous variables as well as monetary disturbances.<sup>19</sup> Hence, in the face of monetary shocks, output and hours worked in the housing sector will remain unchanged. By making prices in this sector more sticky the increase in the relative price  $q_t$  becomes less pronounced – compared to the flex-price case – which, in turn, strengthens the incentive to increase demand for new houses (see equation (B.1)).

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<sup>19</sup>Note that in this case the path of  $N_{d,t}$  still depends on productivity shocks.