Housing, the Credit Market and Unconventional Monetary Policies: From the Sovereign Crisis to the Great Lockdown

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Abstract

This paper develops a two-country model of a monetary union to evaluate the interaction between housing and unconventional monetary policies. The model is calibrated for the Euro Area and assesses the ECB's Asset Purchase Programmes (APP) from 2015 until the Pandemic Emergency Purchase Programme (PEPP) in 2020. The model incorporates heterogeneous households, portfolio balance effects, a credit market susceptible to default, and nominal and real rigidities. In this paper the 2020 lockdown is studied as a negative signal from macroeconomic fundamentals which causes labor to grind to a halt. The model features the housing accelerator and the post-crisis house price double-dip. The findings illustrate the way in which macro-housing channels lead to self-reinforcing loops, affecting the portfolio re-balancing channel as the asset purchase's main way to influence the economy. The results show that the asset purchasing performs better during a crisis, particularly if it is conducted for an appropriate extent of time. The findings illustrate that the PEPP should be extended until the covid-19 crisis phase is over and it alone is not sufficient to accelerate the recovery; more actions namely targeted fiscal policy is required. Finally, the APP, PEPP and lockdown are assessed through a welfare analysis.

JEL classification: E32, E44, E58, F34.

Keywords: Corona Recession, Inter-bank Market, Quantitative Easing, Housing.

1 Introduction

The key questions addressed by this paper are: *i*) How do housing and the credit market, including the possibility of household defaults on mortgages and rigidity in the housing market, contribute to the economy in the time of crisis? and *ii*) How do housing and unconventional monetary policies interact? To answer these questions, this paper develops a two-country model

*I thank Jérôme Creel, Pablo Winant, Vanessa Strauss-Kahn, Johannes Pfeifer, Jean-Francois Rouillard, Hamidreza Tabaraei, Jean Frederic Noah Ndela, Jaime Préz-Luque, Gonçalo Pina, Davide Romelli and Gabriel Desgranges for their valuable comments. . Declarations of interest: none

with five types of agents: heterogeneous households, heterogeneous financial intermediaries, goods producers, governments and a central bank with the Zero Lower Band. The model is calibrated using data pertaining to the Euro economy. Using this model, the ECB's unconventional monetary policy in the form of Public Sector Purchase Programme (PSPP) is then evaluated over : i) the Asset Purchase Programme (APP) from 2015Q1-2019Q4 and ii) the Pandemic Emergency Purchase Programme (PEPP) which was proposed in response to the recent pandemic and the consequent Europe-wide lockdowns. In this paper, the lockdown is not considered as a shock in the normal dynamic of the model, but is presented as a negative signal from macroeconomic fundamentals which brings labor to a standstill and in so doing prompts a real business cycle. This introduction begins with a review of the contribution of housing and then investigates the ECB's unconventional monetary policy in response to the Great Lockdown.

This paper fuses two strands of the literature: first, crisis studies focused on the financial sector, e.g. Perri and Quadrini (2018), Farhi and Tirole (2018), Lakdawala et al. (2018), Auray et al. (2018), Engler and Steffen (2016), Boissay et al. (2016) and Dedola et al. (2013); and second, the housing literature, e.g. Quint and Rabanal (2013), Rubio (2014) and Rubio and Carrasco-Gallego (2014) to name but a few. This paper contributes to the literature by casting light upon hitherto ignored areas, one such area being the interdependencies between housing and both the financial sector and unconventional monetary policies.[1] This paper complements empirical studies on housing and unconventional monetary policies such as those by Rahal (2016), Huber and Punzi (2018), Gabriel and Lutz (2017) and Chiang et al. (2015) by proposing a model based upon Auray et al. (2018).[2] In Auray et al. (2018), households are all lenders and are connected to saving banks through deposits. Saving banks, in addition, are linked to commercial banks in the inter-bank market and commercial banks are connected to the productive sector by lending capital. This paper improves this model by first featuring a heterogeneity in households by introducing borrower households; second, by introducing a new asset transfer channel, i.e. housing, in households' balance sheets; third, by bridging housing and consumption through a constrained mortgage/credit market with a probability of default; and fourth, by introducing imperfect substitution across mortgages and capital into commercial banks' portfolios.

The above changes add only a modest degree of complexity, yet they substantially affect the dynamics and associated policy implications. The first finding of this paper is the housing accelerator: housing amplifies the shock on the real economy. The contribution of housing and the credit market in both the real and financial economies is more significant than introducing heterogeneity in the banking sector (by comparing the model with and without saving banks). The four main channels involved in this result are as follows.

[1] Jarocinski and Smets (2008) show that variations in the real economy cannot explain developments in the housing market, but that accounting for a policy variable improves the analysis significantly.

[2] The use of the DSGE framework to assess the impacts of quantitative easing is preferable to vector autoregression (VAR) or vector error-correction models (VECM) evidenced by Chen et al. (2016). The specified general equilibrium aspect of DSGE models allows for a more accurate recording of the responses of macroeconomic variables to unconventional monetary shocks.

First, the household balance sheet channel, as evidenced by Mian and Sufi (2014): the house price is an endogenous variable revealed in the housing market in which both lenders and borrowers engage. The interaction of lender's and borrower's balance sheet has a significant role in the house price double-dip, i.e. the house price goes further into decline after an attempt to rebound from the first shock.[3] In addition, the behavior of the housing market influences the lender's decision on deposit issuance. This is crucial for the real economy as deposits are the only source of credit for the financial sector to intermediate between lenders and borrower agents including government, production firms and borrower households.

Second, the loan-to-value (LTV) channel: borrower households are impatient and cannot accumulate capital. In addition, a collateral constraint similar to that in Alpanda and Zubairy (2017) restricts the credit market through a LTV ratio. As a result, the LTV may easily expand or impair their budget constraints. This consequently impacts consumption and the housing market, as seen in data from Mian et al. (2013) and Gerlach-Kristen et al. (2015).

Third, the financial sector balance sheet channel: without a credit market, commercial banks are obliged to invest only in capital. However, this is not the case in reality. In this paper, commercial banks are faced with a portfolio decision between capital and mortgages as their main asset types (Gilchrist and Zakrajšek, 2012 and Antoniades, 2019). The housing market is eminent in this decision and so can affect the real economy. The portfolio decision follows a standard form similar to that of Coeurdacier and Martin (2009) and Alpanda and Kabaca (2020).

Fourth, the spread channel: this channel gives rise to portfolio balance effects. The portfolio of saving banks is composed of loans to commercial banks and government bonds. The housing market, which manipulates the liability side of saving banks through the household balance sheet, also influences the asset side through the spread channel in the inter-bank market; note that the credit and capital markets together indicate the return in the inter-bank market. Through this channel, housing impacts the other markets such as bond and deposit markets.

To better investigate the contribution of housing, this paper studies two forms of frictions in the housing market. First, the mortgage/household default risk: the default risks in this paper have a non-linear distribution following Corsetti et al. (2014), Bi (2012) and Arellano (2008); this distribution is a function of household indebtedness, as illustrated in data from Mian et al. (2017). Such an assumption distinguishes this paper from other mortgage default literature, for example Ferrante (2015), Forlati and Lambertini (2011) and Rabitsch and Punzi (2017), which considers an idiosyncratic default shock. The results indicate that the impact of the household default risk depends on the initial state of the economy. The spread channel, explained above, decides how to lead this impact. Second, housing rigidity[4] in the form of an adjustment cost (Iacoviello, 2015). The results indicate that the rigidity dampens the accelerator aspect of housing by increasing

[3]Similar behavior was seen in US data after the financial crisis, see Ghiaie (2020)

[4]For more details on housing rigidity see empirical works such as Oikarinen (2009), Tsatsaronis and Zhu (2004) and Seek (1983).

the pressure on mortgage demand. This causes commercial banks' portfolio to lean in favor of capital, which in turn benefits output.

This paper assesses the APP by executing a series of perfect foresight simulations based on the ECB's decisions from 2015Q1-2019Q4. When the ECB announces a new decision, a new perfect foresight simulation starts, using the initial conditions based on the state of the previous simulation at that point in time and the shock sequences that agents are now expecting. The findings indicate that the public debt-to-GDP portrays the direction of an asset purchase policy thanks to the spread channel: asset purchases perform better in countries with a higher indebtedness level. The results, in addition, highlight the importance of the signaling channel in improving the performance of the APP where an extended program with bigger purchases signals the agents that the central bank is willing to keep interest rates low.

One principal goal of this paper is to evaluate the interaction between the housing market and unconventional monetary policies in the form of asset purchases.[5] The interaction occurs through the portfolio re-balancing channel empirically evidenced in Huber and Punzi (2018): huge asset purchases by central banks manipulate the bond market primarily, pushing prices up and yields down. This drives credit towards the inter-bank market, increasing the supply of capital and mortgages, thus pushing down the effective mortgage interest rate. As a result, both borrowing and housing demand by borrower households rise, pushing the housing price up. However, the housing market cannot resist against the declining patient demands so the housing price hike turns to a fall right after the first period of each APP's announcement.

To allow for a full discussion of asset purchase programs, this paper also investigates the new ECB policy in response to the corona outbreak, i.e. the PEPP. The pandemic has had diverse impacts on the supply and demand sides.[6] However, the most visible and potentially the most significant effect is on the supply side. In response to the pandemic, national lockdowns were implemented across Europe. As a result of the shuttering of nonessential activities, GDP plunged remarkably: the eurozone economy contracted by 3.8% (EuroStat, April 2020). The situation was even worse for the big European economies including Germany, Spain and France, which experienced the sharpest downturns since World War II (ECB and INSEE).[7]

To evaluate the PEPP, the first step is to model the lockdown. The lockdown halts labor despite workforce availability. As a result, it cannot be considered as a simple shock to the economy. In this paper it is assumed that i) the lockdown shifts the economy to a new equilibrium and ii) the economy stays in this new state only for one period, before returning to the initial state. The computational procedures provide fundamental elements to compute nonlinear

[5] For housing and conventional monetary policies see Goodhart and Hofmann (2008), Assenmacher and Gerlach (2008) and Nocera and Roma (2018). Studies such as Rosenberg (2019) focus more on the linkages between the house price and purchases of mortgage-backed securities and equity injections into big banks.

[6] For instance in France, household consumption expenditures declined by 17.9%. Exports and import fell 6.5% and 5.9% (INSEE, 2020).

[7] For example, France's GDP contraction was -5.8%, Spain's -5.1% and Italy's -4.7%. For France, GDP contracted by 1.6% in the first quarter of 2009 during the global financial crisis, and 5.3% in 1968 during the nationwide general strike.(ECB and INSEE 2020)

perfect foresight paths for this scenario. The computation, fully explained in 5.2, needs to be done backwards, similar to the bank-run modeling in Gertler and Kiyotaki (2015). The results indicate that quantitative easing is of great help to financial markets, but is unable to effectively invigorate the demand side of the economy, namely consumption. As a result, even if the labor market could recover swiftly after the lockdown, the macro-housing and rigidity channels slow down the general recovery. These mechanisms also delay the impact of the expansionary monetary policy on the housing market, as empirically evidenced in Rahal (2016). As a result, this paper suggests more actions, e.g. timely targeted fiscal policies, are needed to step up recovery.

Finally, a welfare analysis enriches the findings of this paper. First, to develop the housing contribution, the welfare effect of the APP, alone and during a crisis, is computed in the models with and without household default risks. The results outline that the welfare effect of the APP during the crisis is much higher (about one and a half times) than that of the APP alone in the both models. In addition, the analysis finds that accounting for household default risks boosts the APP's welfare gain in countries with a high debt but marginally reduces the gain in countries with a low debt. Second, the welfare effects of the recent crisis and consequently the ECB's PEPP are analyzed. The main result is that while the impact of the crisis is long-lasting, the PEPP does not have an enduring impact; it increases welfare mostly in the short run and tends to be insignificant over the lifetime. As a result from the long-term welfare perspective, the findings shows that short-term asset purchase programs are not able to attain their objective and therefore they should be extended until the covid-19 crisis phase is over.

This paper is organized as follows: Section 2 presents the model. Section 3 calibrates the parameters used as per Euro data. Section 4 examines the contribution of the housing and credit markets. Section 5 outlines the ECB's asset purchase program and the recent recession due to the lockdown. Section 6 analyzes the welfare effects of the scenarios outlined in section 5. Section 7 offers a conclusion on the findings of this paper.

2 Model

The model below presents the home country. The foreign country block has a similar structure, unless specified. The variables belonging to the foreign country are denoted with a $*$ superscript. There is a continuum of measure unity of each agent.

2.1 Households

2.1.1 Patient Household

Households are either patient (lender) or impatient (borrower). The patient household's problem is

$$E_t \sum_{j=0}^{\infty} \beta_P^j [\log(c_{t+j}^P - \varphi_c c_{t+j-1}^P) + \varphi_o^P \log o_{t+j}^P - \frac{\varphi_h^P}{1+\psi}(h_{t+j}^P)^{1+\psi}]$$

$$s.t$$

$$c_t^P + d_t + p_t^o(o_t^P - o_{t-1}^P) + ac_t^P = (1-\tau_t) w_t^P h_t^P + r_{t-1}^d \frac{d_{t-1}}{\pi_t} + \Pi_t^h \tag{2.1}$$

where t represents time. A variable without t subscription stands for the steady state value of the respective variable in this paper. $\beta_P < 1$ is the discount factor. φ_c, φ_o^P and φ_h^P are the degrees of habits in consumption, housing utility and labor disutility for patient households, respectively. ψ is the inverse of the Frisch elasticity on labor supply.

In every period, the patient household consumes non-durable goods c_t^P, deposits d_t in the financial sector at rate r_t^d, buys and sells durable goods i.e. housing o_t^P at the house price p_t^o, works by supplying labor h_t^P at wage w_t^P, pays a distortionary tax τ_t on labor income, pays a housing adjustment cost $ac_t^P = \frac{\varphi_{ac}}{2} \frac{p_t^o (o_t^P - o_{t-1}^P)^2}{o^P}$ and finally receives Π_t^h which includes all profits from goods producers and the financial sector as well as all transfers from and to bankrupt and new banks. Π_t^h is detailed in the financial section.

The first-order condition with respect to consumption delivers the Lagrange multiplier λ_t^P

$$\lambda_t^P = \frac{1}{c_t^P - \varphi_c c_{t-1}^P} - \beta_P \frac{\varphi_c}{c_{t+1}^P - \varphi_c c_t^P} \tag{2.2}$$

$$\Lambda_t^P = \beta_P \frac{\lambda_t^P}{\lambda_{t-1}^P} \tag{2.3}$$

The FOC with respect to the patient household's deposits, labor supply and housing, respectively, are

$$\Lambda_{t+1}^P r_t^d = 1 \tag{2.4}$$

$$\varphi_h^P (h_t^P)^{\psi} = w_t^P \lambda_t^P (1-\tau_t) \tag{2.5}$$

$$p_t^o + \frac{\partial ac_t^P}{\partial h_t^P} = \frac{\varphi_o^P}{\lambda_t^P o_t^P} + E_t \Lambda_{t+1}^P [p_{t+1}^o + \frac{\partial ac_{t+1}^P}{\partial h_t^P}] \tag{2.6}$$

2.1.2 Impatient Household

The impatient household's problem is

$$
\begin{aligned}
& E_t \sum_{j=0}^{\infty} \beta_I^j [\log(c_{t+j}^I - \varphi_c c_{t+j-1}^I) + \varphi_o^I \log o_{t+j}^I - \frac{\varphi_h^I}{1+\psi}(h_{t+j}^I)^{1+\psi}] \\
& s.t \\
& c_t^I + r_{t-1}^m (1-\chi_t^m) \frac{m_{t-1}}{\pi_t} + p_t^o (o_t^I - o_{t-1}^I) + \Gamma_t^I + ac_t^I = (1-\tau_t) w_t^I h_t^I + m_t \\
& m_t \leq \theta_m p_t^o o_t^I
\end{aligned}
\tag{2.7}
$$

The impatient's discount factor is β_I, which is assumed to be less than that of the patient to make borrowing and lending possible for the agents. φ_c, φ_o^I and φ_h^I are the degrees of habits in consumption, housing utility and labor disutility for impatient households, respectively. At time t, the impatient household consumes c_t^I, buys and sells housing o_t^I at the price p_t^o, borrows mortgages m_t from the financial sector and pays the mortgage interest at the rate r_{t-1}^m. The borrower works for goods producers at wage w_t^I by providing a supply of labor h_t^I. The borrower household does not accumulate physical capital. There is a risk of a default on loans. The probability of default χ_t^m is

$$
\chi_t^m = \Phi_{t+1}^m \Delta_i + (1 - \Phi_{t+1}^m) * 0 \tag{2.8}
$$

$$
\Phi_t^m = F_{beta}(\text{measure of household indebtedness}, \alpha_i, \beta_i) \tag{2.9}
$$

where Δ_i is the default size and the measure of household indebtedness is the level of mortgage to a multiple ϖ_i of quarterly GDP.[8] In this case, the impatient household transfers $\Gamma_t^I = r_{t-1}^m \chi_t^m \frac{m_{t-1}}{\pi_t}$ to commercial banks to cover for the default. ac_t^I is the housing adjustment cost in the same fashion of ac_t^P. (α_i, β_i) determine the slope of the default probability.

Mortgage demand is restricted by the last equation in problem 2.7, i.e. the collateral constraint. This type of constraint is standard: Justiniano et al. (2015), Alpanda and Zubairy (2016) and Ghiaie and Rouillard (2018), for example. The collateral constraint restricts the mortgage to the fraction θ_m of the housing value. θ_m is the loan-to-value (LTV) ratio set by the policy maker as a macroprudential policy tool. The collateral constraint opens an important channel between the financial sector and the real economy. For instance, a smaller LTV, i.e. a stricter regulation, results in a lower consumption-to-income ratio (Rubio and Carrasco-Gallego, 2014). In addition, the collateral constraint indicates an imminent role for house prices in the impatient's decision; an increase in house prices has two opposite impacts: a negative impact

[8] Choosing household indebtedness as a measure of default is based on the finding of Mian et al. (2017) and Bankowska et al. (2017). It is possible to use other default functions in the literature, for example Campbell and Cocco (2015), Goodhart et al. (2009) and Forlati and Lambertini (2011). However, the distribution or shape of the default function is more important in the quantitative analysis. This paper's main focus is to analyze mechanisms, so the form of the default function does not affect the generality.

on housing demands and at the same time, a positive effect on credit capacity by relaxing the collateral constraint through housing wealth effects.[9]

λ_t^I and λ_t^m are the Lagrange multipliers associated with the budget and collateral constraint, respectively. The FOC with respect to consumption, impatient's housing, mortgage and labor are

$$\lambda_t^I = \frac{1}{c_t^I - \varphi_c c_{t-1}^I} - \beta_I \frac{\varphi_c}{c_{t+1}^I - \varphi_c c_t^I} \tag{2.10}$$

$$\Lambda_t^I = \beta_I \frac{\lambda_t^I}{\lambda_{t-1}^I} \tag{2.11}$$

$$1 - \frac{\lambda_t^m}{\lambda_t^I} = \Lambda_{t+1}^I r_t^m \tag{2.12}$$

$$\varphi_h^I (h_t^I)^\psi = w_t^I \lambda_t^I (1 - \tau_t) \tag{2.13}$$

$$(1 - \frac{\lambda_t^m}{\lambda_t^I}\theta_m + \frac{\partial ac_t^I}{\partial h_t^I})p_t^o = \frac{\varphi_o^I}{\lambda_t^I o_t^I} + E_t \Lambda_{t+1}^I [p_{t+1}^o + \frac{\partial ac_{t+1}^I}{\partial h_t^I}] \tag{2.14}$$

2.2 Financial sector

2.2.1 Saving Bank

The representative saving bank solves a two-step problem. First, the bank finds out the level of its asset. Then, it decides how to allocate between different types of assets using a nested CES structure.

The first step is as follows. At time t, the saving bank receives deposits d_t. Deposits are added to the bank's net worth n_t^s to form the bank's asset portfolio a_t^s. At the next period, the bank receives the return r_{t+1}^a on its asset and repays return r_t^d on deposits to patient households. As a result, the bank's balance sheet and the evolution of net worth, respectively, are

$$a_t^s = d_t + n_t^s \tag{2.15}$$

$$\begin{aligned} n_{t+1}^s &= r_{t+1}^a a_t - r_t^d d_t + \Gamma_t^g \\ &= (r_{t+1}^a - r_t^d) a_t + r_t^d n_t^s + \Gamma_t^g \end{aligned} \tag{2.16}$$

Γ_t^g is a damage transfer from the government if a sovereign default occurs; this is explained later in the government section.

At the beginning of each period, the bank either fails and transfers its net worth to households with the probability $1 - \sigma$ or can continue functioning with probability σ. In the case of failure, the bank transfers its net worth to patient households. Then new banks start operating through a start-up fund from patient households. If the bank is still alive, it continues functioning by

[9] The impacts of the housing wealth effect on households' balance sheet are empirically evidenced in Aladangady (2014) and Christelis et al. (2015). For more details on the LTV, see Kok and Lichtenberger (2007).

receiving deposits and issuing loans, as explained before in equ 2.15-2.16.[10] As a result, the bank's value function is the expected present value of the next-period net worth. It is possible to show the value function recursively as a Bellman equation

$$v_t^s = E_t[\Lambda_t^P((1-\sigma)n_{t+1}^s + \sigma v_{t+1}^s)] \tag{2.17}$$

Every period, the bank is able to divert the fraction α_s of its assets for its own benefit and leave the market. This assumption is necessary to confine the expansion of the bank's lending. It is not possible to divert all assets because assets have a degree of illiquidity. As a result, the bank is faced with a simple agency problem

$$v_t^s \geq \alpha_s a_t^s \tag{2.18}$$

This incentive compatibility constraint impedes liabilities such that the bank's benefit for operating normally is greater than that of diverting assets. So the bank's problem is to maximize the value function 2.17 subject to the constraint 2.18. A simple solution for this problem is to assume $v_t^s = \gamma_t^a a_t^s + \gamma_t^s n_t^s$. Substituting this assumption into the bank's problem gives

$$v_t^s = E_t[\Lambda_t^s((r_{t+1}^a - r_t^d)a_t + r_t^d n_t^s)] \tag{2.19}$$

$$\Lambda_t^s = \Lambda_{t+1}^P[1 - \sigma + \sigma(\gamma_{t+1}^a \phi_{t+1}^s + \gamma_{t+1}^s)] \tag{2.20}$$

$$\phi_t^s n_t^s \geq a_t, \quad \phi_t^s = \frac{\gamma_t^s}{\alpha_s - \gamma_t^a} \tag{2.21}$$

This solution indicates that the asset to net worth ratio ϕ_t^s, or in other words the leverage ratio $\frac{\phi_t^s - 1}{\phi_t^s}$, are endogenouse variables set by the market. As a result

$$\gamma_t^a = E_t[\Lambda_t^s(r_{t+1}^a - r_t^d)] \tag{2.22}$$

$$\gamma_t^s = E_t[\Lambda_t^s r_t^d] \tag{2.23}$$

or in the recursive form

$$\gamma_t^a = \Lambda_{t+1}^P((1-\sigma)(r_{t+1}^a - r_t^d) + \sigma\gamma_{t+1}^a \frac{\phi_{t+1}^s}{\phi_t^s}((r_{t+1}^a - r_t^d)\phi_t^s + r_t^d))$$

$$\gamma_t^s = 1 - \sigma + \sigma\Lambda_{t+1}^P \gamma_{t+1}^s((r_{t+1}^a - r_t^d)\phi_t^s + r_t^d)$$

γ^a and γ^s are the discounted marginal benefits of raising one unit of asset by using the deposit and the net worth, respectively. At the aggregate level, the evaluation of net worth for all saving

[10]This structure secures a steady state for the model. Otherwise the bank's net worth is explosive and not stationary. The structure is standard; see Gertler and Kiyotaki (2015) and Gertler et al. (2016).

banks is

$$n_t^s = \sigma((r_t^a - r_{t-1}^d)\phi_{t-1}^s + r_{t-1}^d)n_{t-1}^s + \Gamma_t^g) + (1-\sigma)\Upsilon^s a_{t-1} \tag{2.24}$$

where $\Upsilon^s a_{t-1}$ is the start-up fund from patient households to start new banks in the event of failure.

The bank's problem above is to determine the level of asset. After doing so, the bank decides on the composition of its portfolio. To do so, the bank solves a CES function to decide how to participate in: *i*) the inter-bank market by issuing loans l_t^s to commercial banks and *ii*) the international open bond market by buying home sovereign bonds b_t or foreign sovereign bonds b_t^*. The solution to the CES problem depends on the return of each type of asset. The optimal allocation leads to

$$a_t = [\mu^{\frac{1}{\epsilon}}(l_t^s)^{\frac{\epsilon-1}{\epsilon}} + \eta^{\frac{1}{\epsilon}} b_t^{\frac{\epsilon-1}{\epsilon}} + (1-\mu-\eta)^{\frac{1}{\epsilon}}(b_t^*)^{\frac{\epsilon-1}{\epsilon}}]^{\frac{\epsilon}{\epsilon-1}} \tag{2.25}$$

$$l_t^s = \mu E_t(\frac{r_t/\pi_{t+1}}{r_t^a})^{\epsilon} a_t \tag{2.26}$$

$$b_t = \eta E_t(\frac{r_t^b(1-\chi_t)/\pi_{t+1}}{r_t^a})^{\epsilon} a_t \tag{2.27}$$

$$b_t^* = (1-\mu-\eta)E_t(\frac{r_t^{b*}(1-\chi_t^*)/\pi_{t+1}}{r_t^a})^{\epsilon} a_t \tag{2.28}$$

r_t, r_t^b and r^{b*} are the returns on inter-bank loans, home sovereign bonds and foreign sovereign bonds (in case of no sovereign default), respectively. χ_t and χ_t^* are the probabilities of home and foreign sovereign default, respectively, which are explained in the government section. π_t is the inflation rate. μ and η indicate the relative weights of inter-bank loans and home sovereign bonds in the bank's portfolio. ϵ is the elasticity of substitution.

2.2.2 Commercial Bank

Similar to the saving bank, the commercial bank solves a two-step problem. First, the commercial bank ascertains the level of its asset a_t^c. Then, the bank structures its asset portfolio by choosing between different types of assets i.e. capital k_t and mortgages m_t^c. The commercial bank sets up its asset by borrowing loans l_t^c in the inter-bank market and using its net worth n_t^c. The bank's balance sheet and evolution of net worth are as so

$$a_t^c = n_t^c + l_t^c \tag{2.29}$$

$$\begin{aligned} n_{t+1}^c &= r_{t+1}^c a_t^c - r_t l_t^c + \Gamma_t^I \\ &= (r_{t+1}^c - r_t)a_t^c + r_t n_t^c + \Gamma_t^I \end{aligned} \tag{2.30}$$

similar to the saving bank, the commercial bank's problem is

$$v_t^c = E_t[\Lambda_t^P((1-\sigma)n_{t+1}^c + \sigma v_{t+1}^c)]$$
$$v_t^c \geq \alpha_c a_t^c \tag{2.31}$$

Every period, the bank is able to divert the fraction α_c of its assets for its own benefit and leave the market. The solution to the problem is assumed to be in the form of $v_t^c = \gamma_t^k a_t^c + \gamma_t^c n_t^c$. As a result

$$v_t^c = E_t[\Lambda_t^c((r_{t+1}^c - r_t)a_t^c + r_t n_t^c)] \tag{2.32}$$
$$\Lambda_{t+1}^c = \Lambda_{t+1}^P[1 - \sigma + \sigma(\gamma_{t+1}^k \phi_{t+1}^c + \gamma_{t+1}^c)] \tag{2.33}$$
$$\phi_t^c n_t^c = a_t^c, \quad \phi_t^c = \frac{\gamma_t^c}{\alpha_c - \gamma_t^k} \tag{2.34}$$

where

$$\gamma_t^k = E_t[\Lambda_{t+1}^c(r_{t+1}^c - r_t)] \tag{2.35}$$
$$\gamma_t^c = E_t[\Lambda_{t+1}^c r_t] \tag{2.36}$$

or in the recursive form

$$\gamma_t^k = \Lambda_{t+1}^P((1-\sigma)(r_{t+1}^c - r_t) + \sigma\gamma_{t+1}^k \frac{\phi_{t+1}^c}{\phi_t^c}((r_{t+1}^c - r_t)\phi_t^c + r_t))$$
$$\gamma_t^c = 1 - \sigma + \sigma\Lambda_{t+1}^P \gamma_{t+1}^c((r_{t+1}^c - r_t)\phi_t^c + r_t)$$

γ^k and γ^c are the discounted marginal benefits of raising one unit of asset by using the loans and the net worth, respectively. At the aggregate level, the evaluation of net worth for all commercial banks is

$$n_t^c = \sigma((r_t^c - r_{t-1})\phi_{t-1}^c + r_{t-1})n_{t-1}^c + \Gamma_t^I) + (1-\sigma)\Upsilon_c a_{t-1}^c \tag{2.37}$$

where $\Upsilon_c a_{t-1}^c$ is the start-up fund from patient households to start new banks in the event of failure.

After determining the level of asset, the commercial bank chooses its asset portfolio of capital and mortgages. The asset is a CES function, so

$$a_t^c = [\mu_c^{\frac{1}{\epsilon_c}}(q_t k_t)^{\frac{\epsilon_c - 1}{\epsilon_c}} + (1-\mu_c)^{\frac{1}{\epsilon_c}}(m_t^c)^{\frac{\epsilon_c - 1}{\epsilon_c}}]^{\frac{\epsilon_c}{\epsilon_c - 1}} \tag{2.38}$$
$$q_t k_t = \mu_c E_t(\frac{r_t^k/\pi_{t+1}}{r_t^c})^{\epsilon_c} a_t^c \tag{2.39}$$
$$m_t^c = (1-\mu_c)E_t(\frac{r_t^m(1-\chi_t^m)/\pi_{t+1}}{r_t^c})^{\epsilon_c} a_t^c \tag{2.40}$$

r_t^k and r_t^m are the return on capital and mortgages, respectively. χ_t^m is the probability of household default, which is explained in the impatient household's problem. μ_c and η_c indicate the relative weights of capital and mortgages in the bank's portfolio. ϵ_c is the elasticity of substitution.

2.3 Producers

The productive sector of the economy features different nominal and real rigidities. By applying these features, the model is able to apprehend hump-shaped impulse responses to shocks as one of the properties of business cycle dynamics (Smets and Wouters, 2003 and Smets and Wouters, 2007)

2.3.1 Intermediate goods producer

A perfectly competitive goods market is characterized by constant returns to scale. The identical firms of measure one produce intermediate goods according to the Cobb-Douglas technology, where the utilization rate is u_t. Patient and impatient households work for firms with labor elasticities ι_p and $1-\iota_p$, respectively. The firms borrow capital k_t from commercial banks to produce output y_t^m

$$y_t^m = \varsigma_t (u_t \xi_t^k k_{t-1})^{\iota} ((h_t^P)^{\iota_p} (h_t^I)^{1-\iota_p})^{1-\iota} \tag{2.41}$$

ς_t is total factor productivity and ι the output elasticity of capital. $\xi_t^k = (1-\rho_k) + \rho_k \xi_{t-1}^k - \epsilon_t^k$ is the capital quality shock. Factor prices are the result of the first-order conditions with respect to labor and utilization, as follows

$$p_t^m \iota_p (1-\iota) \frac{y_t^m}{h_t^P} = w_t^P \tag{2.42}$$

$$p_t^m (1-\iota_p)(1-\iota) \frac{y_t^m}{h_t^I} = w_t^I \tag{2.43}$$

$$p_t^m \iota \frac{y_t^m}{u_t} = \delta_t' \xi_t^k k_{t-1} \tag{2.44}$$

where $\delta_t = \delta + \frac{\overline{\delta}(u_t^{1+\kappa}-1)}{1+\kappa}$ and $\overline{\delta} = r^k - (1-\delta)$. In addition, the zero-profit condition implies

$$q_{t-1} r_t^k = \frac{p_t^m \iota y_t^m}{k_{t-1}} + q_t \xi_t^k (1-\delta_t) \tag{2.45}$$

2.3.2 Capital producers

Perfectly competitive capital producers produce capital subject to an adjustment cost. The capital producer maximizes

$$E_t \sum_{j=0}^{\infty} \Lambda^P_{t+j+1}[q_{t+j} i_{t+j}(1 - \frac{\varphi_i}{2}(\frac{i_{t+s}}{i_{t+s-1}} - 1)^2) - i_{t+s}]$$

where the real price of capital is q_t and i_t is investment. The first-order condition for capital production reveals the capital price

$$q_t - 1 = q_t \varphi_i((\frac{i_t}{i_{t-1}} - 1)\frac{i_t}{i_{t-1}} + (\frac{i_t}{i_{t-1}} - 1)^2/2) - E_t[\Lambda^P_{t+1} q_{t+1} \varphi_i(\frac{i_{t+1}}{i_t} - 1)(\frac{i_{t+1}}{i_t})^2] \tag{2.46}$$

The law of motion of capital is therefore

$$i_t(1 - \frac{\varphi_i}{2}(\frac{i_t}{i_{t-1}} - 1)^2) = k_t - (1 - \delta_t)\xi^k_t k_{t-1} \tag{2.47}$$

2.3.3 Final goods producers

A very standard price rigidity is presented to the model à la Christiano et al. (2005). Final goods producers use the intermediate good y^m_t to produce final output y_t at the aggregate price p_t. Final output is a CES composite of a continuum of mass unity of differentiated retail firms. Intermediate output is used as the sole input. Hence, output is

$$y_t = (\int_0^1 y_t(s)^{\frac{\theta-1}{\theta}} ds)^{\frac{\theta}{\theta-1}}$$
$$p_t = (\int_0^1 p_t(s)^{1-\theta} ds)^{\frac{1}{1-\theta}}$$

where $y_t(s)$ is the output of producers. The dispersion of prices p^π_t is

$$p^\pi_t = \int_0^1 (\frac{p_t(s)}{p_t})^{-\theta} ds$$

so that $y_t^m = p_t^\pi y_t$. Final goods producers are faced with Calvo price contracts of average length $\frac{1}{1-\gamma}$ with indexation to past inflation γ_p^P. As a result, the optimal pricing conditions are

$$p_t^\pi = \gamma_p p_{t-1}^\pi \pi_{t-1}^{-\gamma_p^P \theta} \pi_t^\theta + (1-\gamma_p)[\frac{1-\gamma_p \pi_{t-1}^{\gamma_p^P(1-\gamma_p)} \pi_t^{\gamma_p - 1}}{1-\gamma_p}]^{\frac{-\theta}{1-\gamma_p}} \tag{2.48}$$

$$f_t = y_t p_t^m + \Lambda_{t+1}^P \gamma_p \pi_{t+1}^\theta \pi_t^{-\theta\gamma_p^P} f_{t+1} \tag{2.49}$$

$$z_t = y_t + \Lambda_{t+1}^P \gamma_p \pi_{t+1}^{\theta-1} \pi_t^{\gamma_p^P(1-\theta)} z_{t+1} \tag{2.50}$$

$$\pi_t^s = \frac{\theta}{\theta-1} \frac{f_t}{z_t} \pi_t \tag{2.51}$$

$$\pi_t^{1-\theta} = \gamma_p \pi_{t-1}^{\gamma_p^P(1-\theta)} + (1-\gamma_p)(\pi_t^s)^{1-\theta} \tag{2.52}$$

and the mark-up is $\frac{1}{p_t^m}$.

2.4 Government and Central Bank

The budget constraint of the government is

$$b_t^g = r_t^b(1-\chi_t)\frac{b_{t-1}^g}{\pi_t} + g_t - \tau_t(w_t^P h_t^P + w_t^I h_t^I) - \Pi_t^{cb} + \Gamma_t^g \tag{2.53}$$

where b_t^g is the real level of debt. r_t^b is the interest on bonds. g_t is government expenditure. τ_t is the tax rate. It follows that there is a sustainable fiscal rule as

$$\tau_t - \tau = \rho_\tau(\tau_{t-1} - \tau) + (1-\rho_\tau)\varphi_g(\frac{b_t^g}{y_t} - \frac{b^g}{y}) \tag{2.54}$$

φ_g is the fiscal rule parameter and ρ_τ is the tax rule persistence. The tax rate depends on the sovereign indebtedness level. Π_t^{cb} is the nominal operational profits from the central bank if an asset purchase program is operated. This situation is explained later in section 5. χ_t is the ex-ante probability of sovereign default.[11] Following the literature, i.e. Batini et al. (2019), this probability is related to the sovereign indebtedness

$$\chi_t = \Phi_{t+1}\Delta + (1-\Phi_{t+1}) * 0 \tag{2.55}$$

$$\Phi_t = F_{beta}(\text{measure of sovereign indebtedness}, \alpha_g, \beta_g) \tag{2.56}$$

where Δ is the default size and (α_g, β_g) determine the slope of the default probability. The measure of sovereign indebtedness is the level of debt to a multiple ϖ of quarterly GDP which determines the debt limit. The government transfers $\Gamma_t^g = r_t^b \chi_t \frac{b_{t-1}^g}{\pi_t}$ to cover for sovereign default.

[11] Following the literature, Corsetti et al. (2014) for example, default mostly matters ex-ante because the losses will be compensated ex-post.

The central bank is independent from the government and follows an occasionally binding constraint

$$\log r_t^n = \max(0, \rho_r \log(r_{t-1}^n) + (1-\rho_r)[\log(r^n) + \varphi_\pi \log \pi_t^u + \varphi_y (\log y_t^u - \log \tilde{y}^u)]) \tag{2.57}$$

where the first term in the maximization is the Zero Lower Band and the second term is the Taylor rule. r_t^n is the common nominal interest rate. Hence, $r_t^d = \frac{r_{t-1}^n}{\pi_t}$. In the Taylor role, $\pi_t^u = \pi_t^{\frac{1}{1+\varrho}} (\pi_t^*)^{\frac{\varrho}{1+\varrho}}$ is the union-wide inflation rate, $y_t^u = y_t^{\frac{1}{1+\varrho}} (y_t^*)^{\frac{\varrho}{1+\varrho}}$ is the union-wide level of output and $\tilde{y}^u$ is output natural level. φ_π and φ_y are Taylor parameters for the inflation and output gaps, respectively. ϱ is the relative size of the foreign economy.

2.5 Market Clearing

Market clearing in the good market is

$$y_t = c_t + i_t + g_t + ac_t \tag{2.58}$$

y_t is considered as GDP, which includes total consumption $c_t = c_t^P + c_t^I$, capital investment, government expenditure and total housing adjustment cost $ac_t = ac_t^P + ac_t^I$. The housing supply is normalized to one, so $o_t^P + o_t^I = 1$, to only focus on the housing demand side. This is standard in the literature on housing, for example in Iacoviello (2015). The international financial market is cleared by

$$l_t^s + \varrho l_t^{s*} = l_t^c + \varrho l_t^{c*} \tag{2.59}$$

$$m_t^c + \varrho m_t^{c*} = m_t + \varrho m_t^* \tag{2.60}$$

for the inter-bank and credit/mortgage markets, respectively. The international bond market is cleared by the level of sovereign debt

$$b_t^g = b_t + \varrho b_{*t} \tag{2.61}$$

where b_{*t} is the level of home bonds bought by foreigners. It is important to note that the nominal rates on both loan and mortgage markets are common. Both countries are in a monetary union with a single central bank. However, each country has its own real return depending on the inflation rates.

A set of prices and allocations defines an equilibrium so that households and banks maximize their utility functions subject to their respective constraints and all markets are cleared (markets for goods, housing, bonds, credits, loans, labor, deposits, mortgages and capital).

3 Calibration

Table 1: Calibrated parameters (quarterly)

Parameters	Symbol	Value
Discount factors	β_P, β_I	$0.9941, 0.9880$
Consumption preference	φ_c	0.815
Housing preference, patient	φ_o^P	0.028(0.025)*
Housing preference, impatient	φ_o^I	0.19(0.17)
Housing adjustment cost	φ_{ac}	0
Inverse of the Frisch elasticity	ψ	3
Capital depreciation rate	δ	0.018
Utilization parameter	κ	7.2
Probability of survive	σ	0.975
Loan-to-value ratio	θ_m	0.38(0.31)
Investment Adj. cost	φ_i	1.72
Coef. of start-up funds	Υ_s, Υ_c	$0.008, 0.004$
Coef. of assets in the ICC	α_s, α_c	$0.59, 0.59$
Elasticity of capital	ι	0.33
Elasticity of patient labor	ι_P	0.35
Calvo parameter	γ_p	0.779
Indexation parameter	γ_p^P	0.241
mark-up parameter	θ	4.33
shock persistence	ρ_k	0.33
Tax rate	τ	0.44(0.35)
Fiscal rule persistence	ρ_τ	0.90
Fiscal rule parameter	φ_g	0.025
Monetary persistence	ρ_r	0.80
Taylor rule parameters	φ_π, φ_y	$2, 0.125$
Default probability parameters	$\alpha_{(g,i)}, \beta_{(g,i)}$	$3.7, 0.54$
Default size	Δ, Δ_i	$0.55, 0$
Multiples in the default functions	ϖ, ϖ_i	$0.64, 0.155$
Share of inter-bank lending	μ	0.84
Share of capital lending	μ_c	0.22
Share of domestic debt	η	0.13(0.09)
Elasticity of substitution	ϵ, ϵ_c	$654, 2111$
Relative size of the foreign eco.	ϱ	0.5959

*The values in parenthesis belong to the foreign country

The model is calibrated for the Euro Area to capture key euro area stylized facts over 2009-2015.[12] The parameter values are presented in figure 1. Following the literature, i.e. Lakdawala et al. (2018) and Auray et al. (2018), the same parameter choices are opted in the two countries unless otherwise specified. The foreign country in the model includes Portugal, Ireland, Italy, Greece and Spain.[13] The home country is consist of the other members of the monetary union.

[12]This period presents the post 2008 crisis situation in the Euro Area. The calibration methodology varies in the literature: Sahuc (2016) uses the data before 2007 to calibrate its model and evaluates the APP's impact started in Jan 2015, Andrade et al. (2016) use the euro area long-term data from 1999 to 2015.

[13]They can be also called periphery countries. These are the countries which by the end of 2009 were not able to service their debt or assistant their banks without an external help. As a result, international financial organizations such as the ECB, IMF and EFSF stepped in to bail them out.

The discount factors are set to target the deposit interest rate at 2.40% and the mortgage interest at 3.19%, from ECB data (EU Area Statistics, Bank interest rates - Loans).[14] The depreciation rate guarantees 17% investment to GDP annually. The elasticity of capital in production function is calibrated to target capital to GDP equal to 2.31 annually. This value and the depreciation rate pin down the capital interest rate at 3.85% annually, which is consistent with ECB data. Housing preferences are set to target total housing value to GDP equal to 1.3 for the home country and 1.25 for the foreign country annually, and a share of 35% and 45% for patient housing, all based on ECB Structural Housing Indicators Statistics. The LTV is calibrated so that mortgage to GDP stands at 1.2 and 1 for the home and foreign countries, based on ECB Indicators (Euro Area Statistics, Household Indebtedness). The coefficients of assets in the incentive compatibility constraint are set so that the asset to net worth ratios are 2.5, based on ECB data (MFI). This implies that aggregate net worths for both banks are 40% of their assets and, accordingly, pins down the value of the coefficients of start-up funds. The tax rates are calibrated to bind the government budget constraint when government expenditures are 20% and 19% for the home and foreign countries, respectively.

The elasticity of patient labor is set such that patient working hours are equal to 0.25 and 0.30 for the home and foreign countries, respectively, based on OECD data. The values for the elasticity of substitution in the saving banks' assets are set so that market clearing in the financial market is respected given that the interest rate on inter-bank loans is 2.12% annually based on ECB data (EU Area Statistics, Bank interest rates - Deposits). The shares of inter-bank lending and domestic debt are calculated so that the shares of domestic debt held by domestic agents are 81% and 60% for the home and foreign countries, given that the bond interest rates are 3.4% and 3.9% annually reported by the OECD. The share of mortgage in the commercial banks' portfolio is calibrated to satisfy the mortgage market clearing condition, given the mortgage interest rate. The other values which are not responsible for the steady state or are fairly standard in the literature come from Auray et al. (2018). Table 2 presents the the steady state values of important macro variables in the model.

Table 2: The steady state values of variables to GDP

Variables	Symbol	value/annual GDP
Consumption	c	0.62(0.64)
Investment	i	0.17(0.17)
Gov. expenditure	g	0.20(0.19)
Capital	k	2.31(2.31)
Gov. debt	b^g	0.65(0.75)
Tax revenue	$\tau(w^P h^P + w^I h^I)$	0.23(0.20)

*The values in parentheses belong to the foreign country

[14]Note that the Lagrangian multiplier of the collateral constraint has a role in adjusting the mortgage interest rate.

4 Diagnosis

This section highlights the macro-housing channels and how housing impacts the real economy. To do so, this section first compares the dynamics of the base model with both the model without housing and credit market and that without housing and saving banks. The household default is ignored at this stage, i.e. $\Delta_i = 0$, to allow the significance of housing alone to be evaluated. Then the contribution of the inclusion of the household default is assessed. Finally, a sensitivity analysis studies the impact of rigidity in the housing market.

4.1 Contribution of housing and the credit market

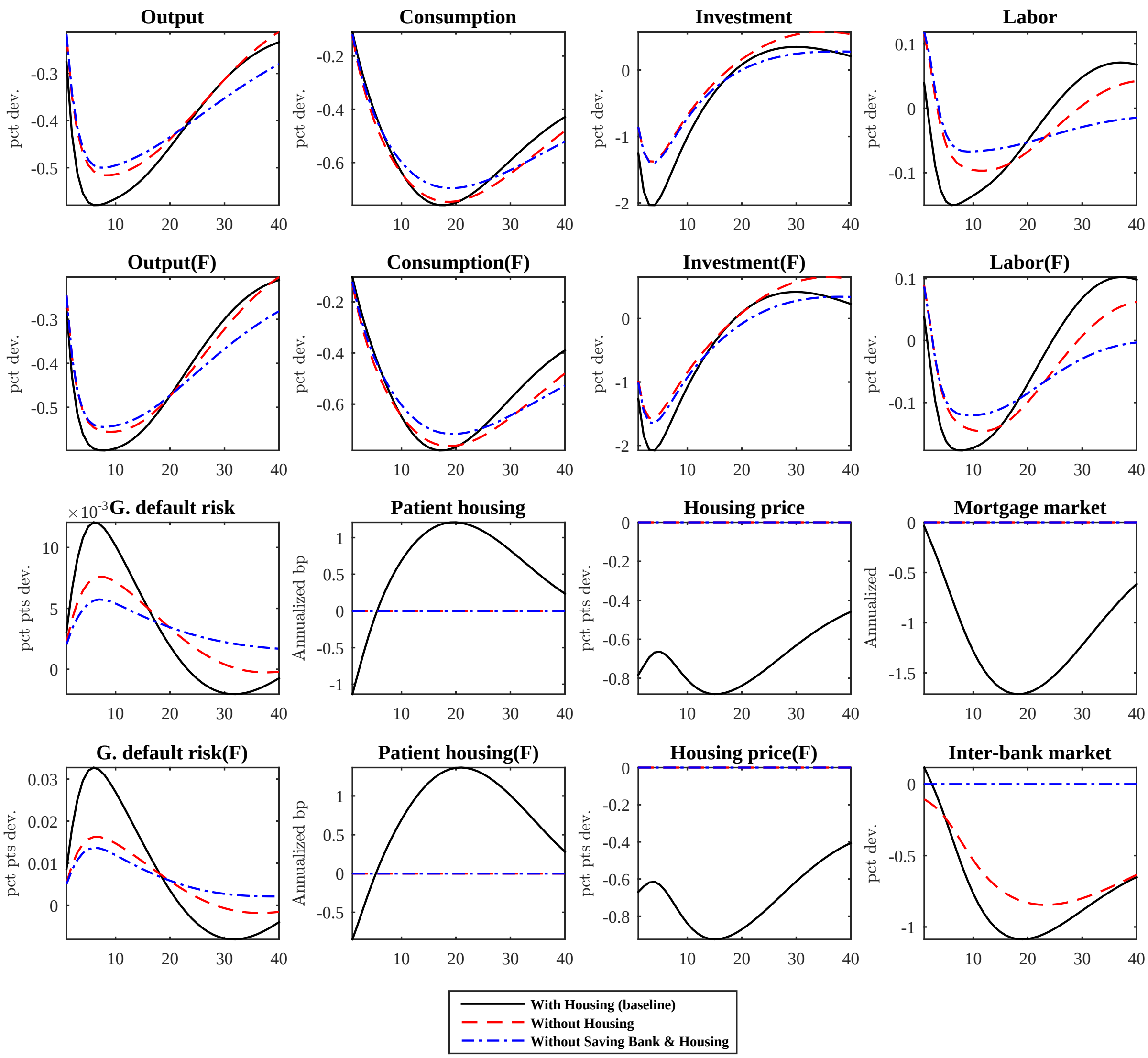

Figure 1: Impact of 1% negative capital quality shock. The time horizon is quarterly. Panels with (F) belong to the foreign country.

Figure[15] 1 presents the impulse responses to a 1% negative shock to the capital quality ξ_t^k for three models: the base model, model without housing and credit market, and model without housing and the inter-bank market, i.e. without saving banks.[16]

The results show that the contribution of housing in both the real and the financial economy is greater than that of introducing heterogeneity in the financial sector (by comparing the model with and without saving banks). The following are the characteristics that all models share. The capital quality shock reduces the marginal productivity of capital. This contracts output and consequently consumption and investment. The recession enlarges the government debt to GDP ratio. As a result, the probability of government default which depends on the level of government indebtedness, undergo a hike. In addition, all models share a slow recovery, which is mostly derived from deleveraging in the financial sector throughout the crisis and its impact on the progress of capital investment as it returns to trend.

The results indicate precisely the importance of including housing in the model: housing amplifies the shock on the real economy, namely output and investment. This is the *housing accelerator*. The macro-housing and macro-financial channels play an extremely important role in shaping the dynamics of the model. These channels and mechanisms are summarized in the following four points.

First, the household balance sheet channel: as explained previously, the shock impairs the household's balance sheet by reducing wages. As a result, patient households decrease their housing demands, deposits and consumption. This reduces the house price which also spreads into the deposit market by causing a deposit crunch. In particular, the decline in loans to the financial sector drags down both consumption and investment. This channel is explained in the next paragraph. On the side of impatient households, the decline in patient housing is not fully offset by borrower housing demand, and the aggregate housing price declines. This involves the second channel, the LTV channel, in the mechanisms.

Second, the LTV channel: the drop in the house price tightens the collateral constraint. The tightened collateral constraint pushes down supply in the mortgage market. This channel highlights the role of the LTV in transmitting shocks between the real and financial economies. The lower the LTV, the more significant this channel.

Third, the financial sector balance sheet channel: the shock puts pressure on both the asset and the liability sides of the balance sheet of both saving and commercial banks. On the asset side, both banks receive less from their assets. This reduces their net worth, which in tur, expands the share of leverage in their assets. This increases the demand for loans, which

[15] In all figures: Y ax: time (quarterly), X ax: pct dev. = percentage deviations from their steady state $100(x_t - x)/x$, pct pts dev. = percentage point deviations $100(x_t - x)$, annualized bp = annual basis-points deviations $40000(x_t - x)$ and annualized = percents per annum $400(x_t - x)$. At time zero, all variables are at zero, i.e. at the steady state. This point is not shown in the figures. The responses are shown from t=1 when the shock hits the economy. Aggregate labor is $h = (h^P)^{\iota_p}(h^I)^{1-\iota_p}$.

[16] All simulations are run under the standard stochastic or deterministic perfect foresight methodology by Dynare. The non-linear Newton-Raphson algorithm is used to simulate forward-looking variables. The details of the methodology are fully explained by Adjemian et al. (2011).

subsequently raises the spreads in the financial market.[17] On the liability side, as explained before, saving banks are faced with a deposit crunch. This reduces the size of the inter-bank market, i.e. damages the supply/liability side of commercial banks, pushing both mortgages and investments down. This channel also indirectly reduces consumption by dragging down both labor demand and output. The latter mechanism connects the household and financial sector balance sheets through the productive side of the economy.

Fourth, the spread channels (portfolio balance channel): both banks seek the optimal investment portfolio based on returns. Given the smaller deposit market, saving banks must decide how to arbitrate between bonds, with a higher government default risk, and loans, with a lower inter-bank return. Commercial banks must also determine their portfolio by choosing between capital and mortgage, given that the returns on both are weakened. In the other models, commercial banks do not have a portfolio, i.e. mortgages are absent, which implicitly leads all loans to be transformed into investment goods at no cost. The portfolio decisions of banks, both saving and commercial, based on spreads, are decisive for directing output and for the other markets such as the bond market.

Figure 1 also features an interesting point regarding the house price: a house price double-dip, i.e. the house price meets a drop-off after a struggle to bounce back from the first shock. The explanation is as follows. After the first shock, as explained in the previous paragraphs, the house price starts to recover due to an increase in patient household demand. This cannot last long: the decline in impatient household demand due to a slackening of the mortgage supply offsets the initial impact. As a result, the house price is pushed down. The house price starts to recover only when the mortgage market begins to rebound.

4.2 Household default risk

This section studies the inclusion of the household default risk in the model. The analysis comes in two parts: i) analysis of the steady state, since the steady state shifts when the household default is imposed, and ii) a study of the channels and mechanisms that a housing default triggers. Table 3 presents the percentage change in the steady state after the household default is introduced. By setting $\Delta_i = 0.55$, the household default risks are 0.036% and 0.01% in the home and foreign countries, respectively. The mechanisms which describe the shift in the steady state are as follows.

Table 3: Percentage changes in the steady state when the household default probability is included

	GDP	Inv.	Consumption	P. Housing	I. Housing	House price	G. default risk
Home	-0.008	-0.05	-0.001	0.65	-0.43	-0.59	0.026
Foreign	0.054	0.12	0.052	0.45	-0.33	-0.38	-0.11

[17] In this model banks are not constrained by a capital constraint in the form of Basel III, for example. If there are such constraints, facing lower returns, banks have to deleverage, i.e. sell their assets to pay off liabilities.

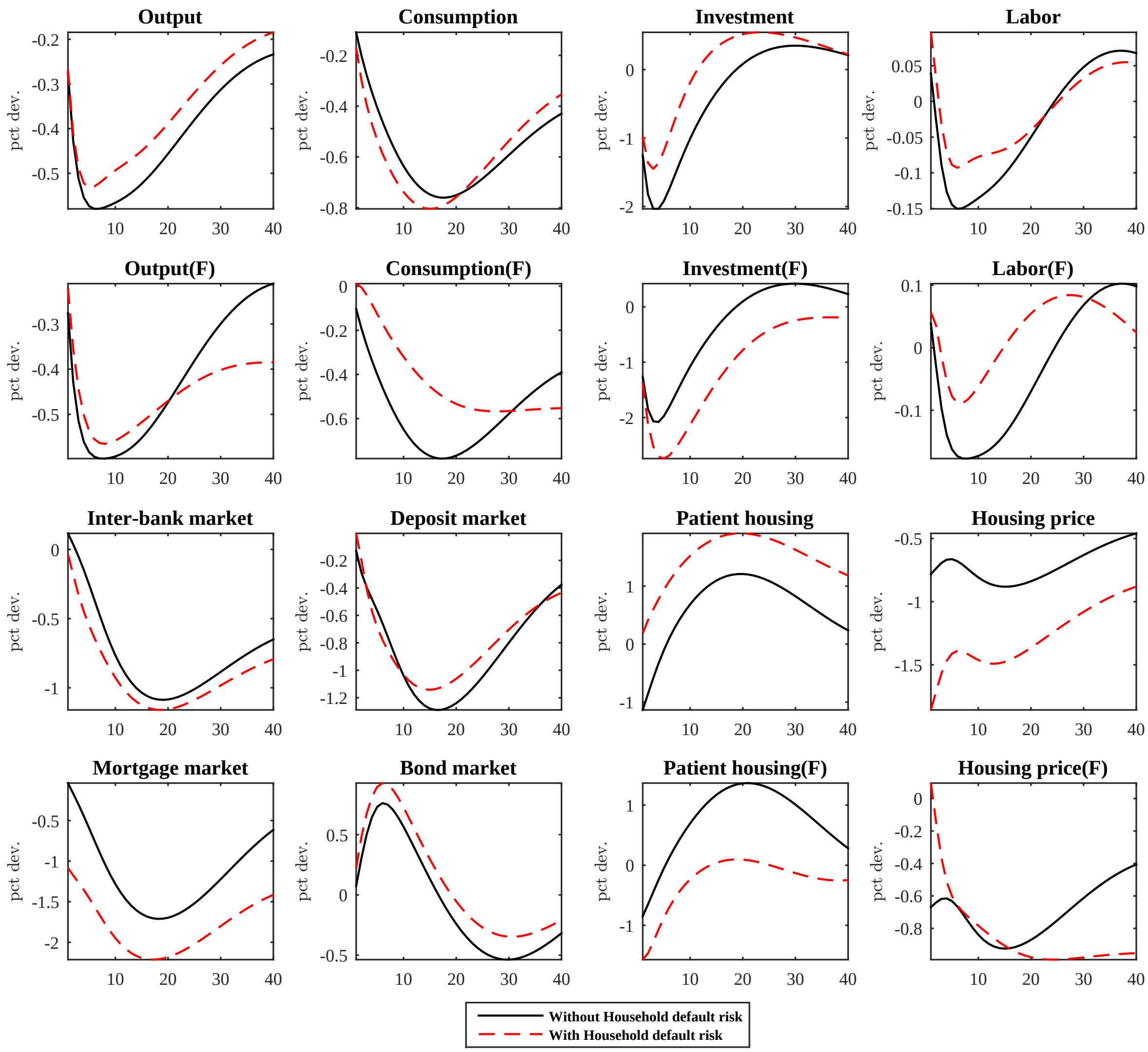

Figure 2: Impact of including the household default risk in the model on the real economy (quarterly).

The household default risk initially brings down the return on mortgages for commercial banks. This leads to a drop in mortgage supply from banks, which in turn increases the mortgage interest rate. This brings down impatient housing and lowers the house price. Impatient consumption at the steady state depends on the mortgage interest return, i.e. $r^m m$. For the home country this bundle insignificantly decreases consumption at the steady state. For the foreign country, the reverse occurs. In both countries, patient households enjoy a lower house price and increase their housing. This pushes deposits down. As a result, the deposit interest rate rises.[18] This shrinks the net worth of saving banks, and accordingly squeezes both the portfolio size and supply in the inter-bank market. The decisions of commercial banks on how to build their portfolio are crucial in forming investment and, accordingly, the direction of output and government default risk. This decision depends on the net worth of banks, the change in spreads

[18] This is consistent with empirical findings by Stanga et al. (2020).

and the level of the inter-bank market.

Figure 2 compares the response of the economy to the capital quality shock described in the previous section, in two scenarios: with and without household default risk. Given that the introduction of housing default changes the steady state, to keep the results comparable, both models start from the same steady state and household default is incorporated from period one. This assumption removes the impact of steady state changes and brings the impact of household default to the forefront. The results indicate the crucial role played by household defaults.

In the first place, the inclusion of the household default risk in the model dampens the size of the recession. This occurs through an increase in investment in the home country and in consumption in the foreign country. The difference in reactions between countries originates in the housing market and the spread between mortgages and capital returns. The mechanisms are as follows. As explained previously, household defaults firstly impact the mortgage return. In the home country, the mortgage-capital spread is such that commercial banks prefer to give more weight to capital. The reverse is true in the foreign country. Impatient housing demand - note that total housing supply is fixed - directly depends on mortgages. As a result, the house price reacts differently in the two countries depending on housing demand. More resources are available to impatient households in the foreign country and thus greater consumption is possible. On the other hand, in the home country, fewer mortgages have the effect of squeezing the impatient budget and in turn reducing consumption. In general, demand in the inter-bank market drops, which in turn causes saving banks to heat the bond market.

4.3 Sensitivity analysis

The base model is not subject to any rigidities in the housing market. This section studies the impact of housing rigidities in the form of housing adjustment costs. Figure 3 compares the response to the capital quality shock in two cases: the base model and the base model plus housing adjustment costs, i.e. $\varphi_{ac} > 0$. Note that introducing the housing rigidity does not change the initial steady state. The impact of the housing adjustment cost on the real economy is significant. It contracts the adverse impact of the capital quality shock, especially on output. This effect is initiated in the housing market and manipulates all three channels outlined in section 4.1. The transmission channels are as follows.

As explained in the previous sections, the capital quality shock causes a decrease in output, wages and capital returns. When the housing adjustment cost is incorporated into the model, the first impact is that households can no longer easily change their housing. This creates two different repercussions on the patient and impatient balance sheets. On the patient side, housing inflexibility adds an extra burden to deposits and causes them to drop further. This in turn reduces the size of the inter-bank market. On the impatient side, the rigidity places huge pressure on mortgage demand, which consequently leads to a protracted decline in both the mortgage market and the house price. This gives commercial banks an incentive to invest more in capital, which in turn mitigates the output decline.

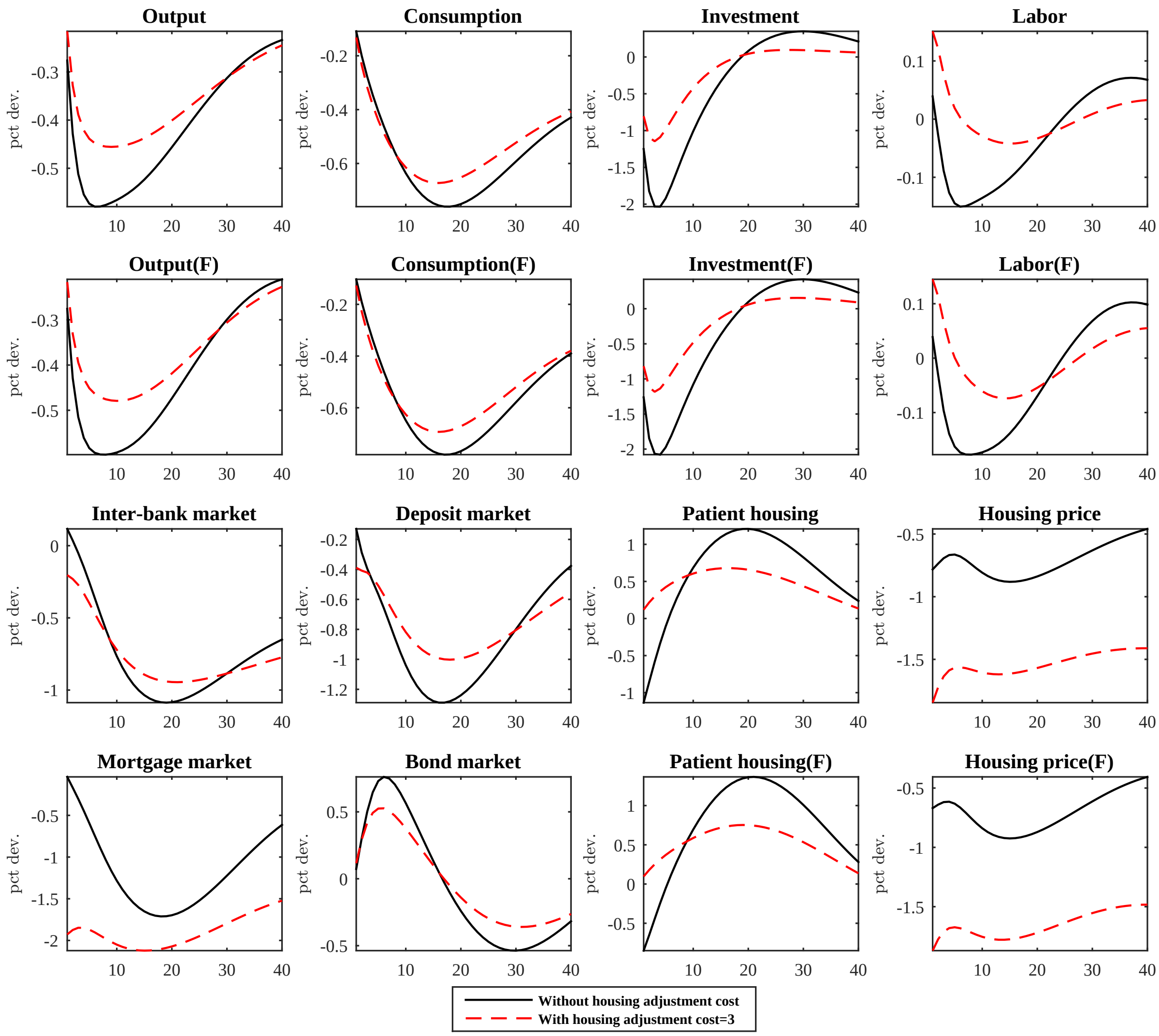

Figure 3: Impact of 1% negative capital quality shock on the real economy (quarterly).

5 Asset Purchase Programs

The APP[19] is modeled here by

$$\Omega_t = \xi_t^{\Omega} y \tag{5.1}$$

[19]This paper only studies the Public Sector Purchase Programme (PSPP) i.e. the purchase of government bonds by the ECB under the APP as "Since December 2018, government bonds make up around 90% of the total Eurosystem portfolio, while securities issued by international organizations and multilateral development banks account for around 10%. These proportions will continue to guide the net purchases."(ECB report, Jan 2020)

where $\xi_t^\Omega \geq 0$ determines the quarterly asset purchases to annual GDP. As a result, output market clearing 2.58 and government debt 2.61 change to

$$y_t = c_t + i_t + g_t + ac_t + \varsigma\Omega_t \tag{5.2}$$

$$b_t^g = b_t + \varrho b_{*t} + \Omega_t \tag{5.3}$$

where ς is the operational cost. The profits of the APP are

$$\Pi_t^{cb} = \frac{1}{1+\varrho}\left(\frac{r_t^b(1-\chi_t)}{\pi_t} - r_{t-1}^d\right)\Omega_{t-1} + \left(\frac{r_t^{b*}(1-\chi_t^*)}{\pi_t} - r_{t-1}^d\right)\varrho\Omega_{t-1}^* \tag{5.4}$$

$$\Pi_t^{cb*} = \frac{\varrho}{1+\varrho}\left(\frac{r_t^b(1-\chi_t)}{\pi_t^*} - r_{t-1}^{d*}\right)\Omega_{t-1} + \left(\frac{r_t^{b*}(1-\chi_t^*)}{\pi_t^*} - r_{t-1}^{d*}\right)\varrho\Omega_{t-1}^* \tag{5.5}$$

which is returned to the governments in equ 2.53.[20]

The following two subsection investigate the macroeconomic impact of the ECB's APP in two periods: i) from March 2015 until the end of 2019 and ii) from 2020Q1 in response to the corona outbreak.

5.1 The APP: 2015Q1-2019Q4

Table 4: The pace of the ECB's monthly purchases 2015Q1-2019Q4. Source: ECB

	Billion Euro
March 2015 to March 2016	60
April 2016 to March 2017	80
April 2017 to December 2017	60
January 2018 to September 2018	30
October 2018 to December 2018	15
November 2019 to December 2019	20

The pace of monthly purchases conducted by the ECB is summarized in table 4. At each quarter $\xi_t^\Omega =$ the ratio of purchases to annual GDP is fed into the model (equ 5.1) until 2019Q4.[21] It is assumed that the purchase is symmetric. For instance, in March 2015, the quarterly purchase represents about 2.3% of each region's annual GDP. The model runs a series of perfect foresight simulations based on the ECB's decisions from 2015Q1-2019Q4.[22] Whenever a new

[20] It is possible to model the APP as risk-less bonds available to patient households. In this case, the profits goes to the patient household's budget. The analyses are also done in this case and the changes are insignificant.

[21] Note that "Between January 2019 and October 2019, the Eurosystem fully reinvested the principal payments from maturing securities held in the APP portfolios. The Governing Council aimed to maintain the size of its cumulative net purchases under each constituent programme of the APP at their respective levels as at the end of December 2018. On 12 September 2019, the ECB Governing Council decided that net purchases will be restarted under the Governing Council's asset purchase programme (APP) at a monthly pace of €20 billion as from 1 November 2019." (ECB report, Jan 2020)

[22] The ECB reports: Decision ECB/2015/10 of 4 March 2015, Decision ECB/2015/33 of 5 November 2015 amending Decision ECB/2015/10, Decision ECB/2015/48 of 16 December 2015 amending Decision ECB/2015/10, Decision ECB/2016/8 of 18 April 2016 amending Decision ECB/2015/10, Decision ECB/2017/1 of 11 January

decision is made and so the new information realizes, the model starts a new simulation, using the initial conditions based on the state of the previous simulation at that point in time and the released shock sequence that agents are now expecting.

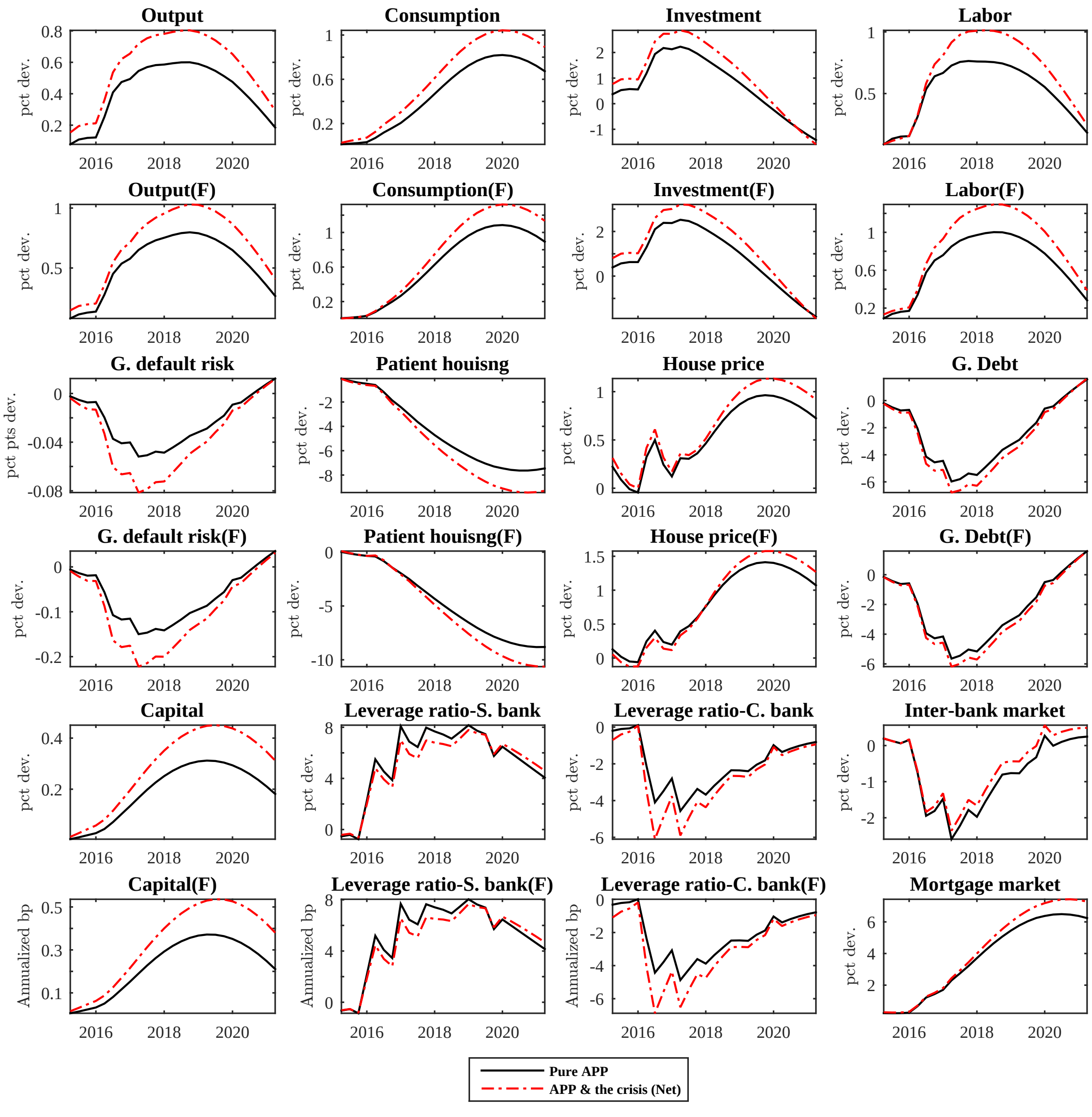

Figure 4: Impact of quantitative easing (asset purchase program) and capital quality shock.

Figure 4 presents the impact of the APP if applied alone or if applied in the presence of a crisis similar to the recent financial crisis i.e. a capital quality shock of size $\epsilon_t^k = 0.07$ in the same way as in section 4.1 hits the economy at period 1. This shock causes a fall equal to 4.5% and 5% in GDP of both home and foreign countries, respectively, as it was seen in 2009. To focus

2017 amending Decision ECB/2015/10.

more on the contribution of the APP, only the APP's net impacts are depicted in the figure. This stands for the difference between responses to the crisis alone and to the crisis with the APP. The responses to the crisis alone are not presented as they are the same as in figure 1, only larger. The analysis is organized into two focuses: first the impact of the APP alone, then the performance of the APP during the crisis.

The APP activates a few channels and mechanisms. These channels are as follows. The APP initially increases demand for government bonds, pushing prices up and yields down. This provokes two channels. First, the patient household balance sheet channel by tapering deposit demands. Second, the saving bank's portfolio rebalancing channel by pushing saving banks to adjust their portfolio towards loans. From here, it is the spread channels which directs the respond of the economy. A higher loan supply lowers the loan premium. This triggers commercial banks to more invest in capital and mortgages. A higher investment level in productive capital boosts output as well as the capital stock and the productivity of workers. This increases labor demand and real wages. This stimulates household consumption. Increasing the mortgage supply tends to lower borrowing rates, leading to an increase in impatient housing. This boosts the housing price. In addition, the APP reduces government debt to GDP, which in turn reduces government default risks. At the beginning of the simulation because of the initial conditions, the APP seems to have insignificant impacts on the variables as the spread channel cannot shift the state of the economy. This changes when the second wave of the APP is announced.

From the second run of the APP, thanks to the size and the new initial conditions, the spread channels are able to reinforce portfolio balance effects in the favor of investment in all balance sheets. As a result, all variables keep the same path as explained above, but this time, by significant responses, namely on output, investment and government default risk. However, the inter-bank market as well as the leverage ratios behave differently. The reason is hidden in the signaling channel. An extended APP with augmented purchases signals the agents that the central bank is willing to continue the quantitative easing. This is interpreted as the signal to lower interest rates than previously expected so banks anticipate a protracted period of low interest rates. The compression of yields pushes down the saving bank's net worth, leading to an increase in the leverage ratio. On the other hand, the output and mortgage growth surges the commercial bank's net work, inducing a decline in the leverage ratio. This pattern inverts after 2017 when the announced APP is characterized by the lower-size monthly purchase pace, signaling the agents that the central bank's interventions are going to be to a smaller extent.

The interaction of the APP and the housing market is important. As explained before, the housing price reacts positively to the asset purchases. However, the housing price boost turns to a decline right after the first period of each announcement. The reason is that the housing price is managed by the interaction between patient and impatient house demands. The impatient house demands are raising thanks to the generous mortgage market, however, the patient house demands are decreasing (note that total housing is normalized to one so patient and impatient house demands move contrariwise). After each APP announcement, the housing price increases initially thanks to the impatient house demands but cannot resist against the declining patient demands.

The results indicate that the APP performs better in the foreign country than the home one, namely on output and government default risk. These differences originate from the debt-to-GDP channel; the higher the level of debt to GDP, the higher the spread variation after the APP. In addition, as explained above, the portfolio rebalancing channel is sensitive to spreads. As a result, the debt-to-GDP channel drives the impact of the APP. For instance, the foreign country carries more initial debt, so it responds more completely to the APP than the home country.

Comparing the result of the APP's performance with and without a crisis in figure 4 reveals another interesting feature: the APP performs better during the crisis and more effectively if it is conducted for an appropriate extent of time. The output variation between two cases is at its maximum in 2019, even though the APP was not officially in force during the first three quarters of 2019. The reason lies in the interaction between the portfolio rebalancing and debt-to-GDP channels, as explained in the previous paragraph.

5.2 The PEPP and the Great Lockdown

This chapter, first, studies the impact of the covid-19 crisis and the lockdown. It then assesses the response of the economy to the ECB's Pandemic Emergency Purchase Programme (PEPP).

The lockdown reduces working hours via a governmental order. This is a new equilibrium in the model; the lockdown is not a shock in the normal dynamic of the model, it is a negative signal from macroeconomic fundamentals which causes a partial shut-down in the labor supply. It is given that the lockdown leads to a recession of -4.3% in home and -3.4% in foreign countries in the first quarter of 2020. This figure is that reported as the contraction in the Euro area from 2019Q4 to 2020Q1 by EuroStat (April 2020). To simplify the analysis, it is also assumed that after 2020Q1 there is no other adverse shock in the model and the lockdown is a one-time event.[23] There are three moves toward figuring out the response of the economy to the lockdown. The computation needs to be done backwards[24]: i) computing the saddle path of the economy from the period after the lockdown back to the initial steady state. After the lockdown, it is assumed that the economy obeys a deterministic path until it converges back to the steady state of 2019Q4. ii) given the path from i and the values of the endogenous variables at 2020Q2, computing the values at 2020Q1. This is the lockdown equilibrium. iii) computing the starting point, which is the steady state of 2019Q4, using the simulation results in section 5.1. What is

[23]The first lockdown was ordered approximately at the same time in all Europ. However, the other lockdowns were imposed (or are still beeing imposed) based on the sanitary situations which vary between countries.

[24]Changing between two states, i.e. crisis equilibrium and normal equilibrium, is similar to the crisis modeling in Gertler and Kiyotaki (2015) and Ghiaie (2020). While the nature of the lockdown is different from other recessions studied in the the crisis literature, the methodology of modeling the problem remains the same.

of help here is that the initial value of the endogenous states of each step is known.

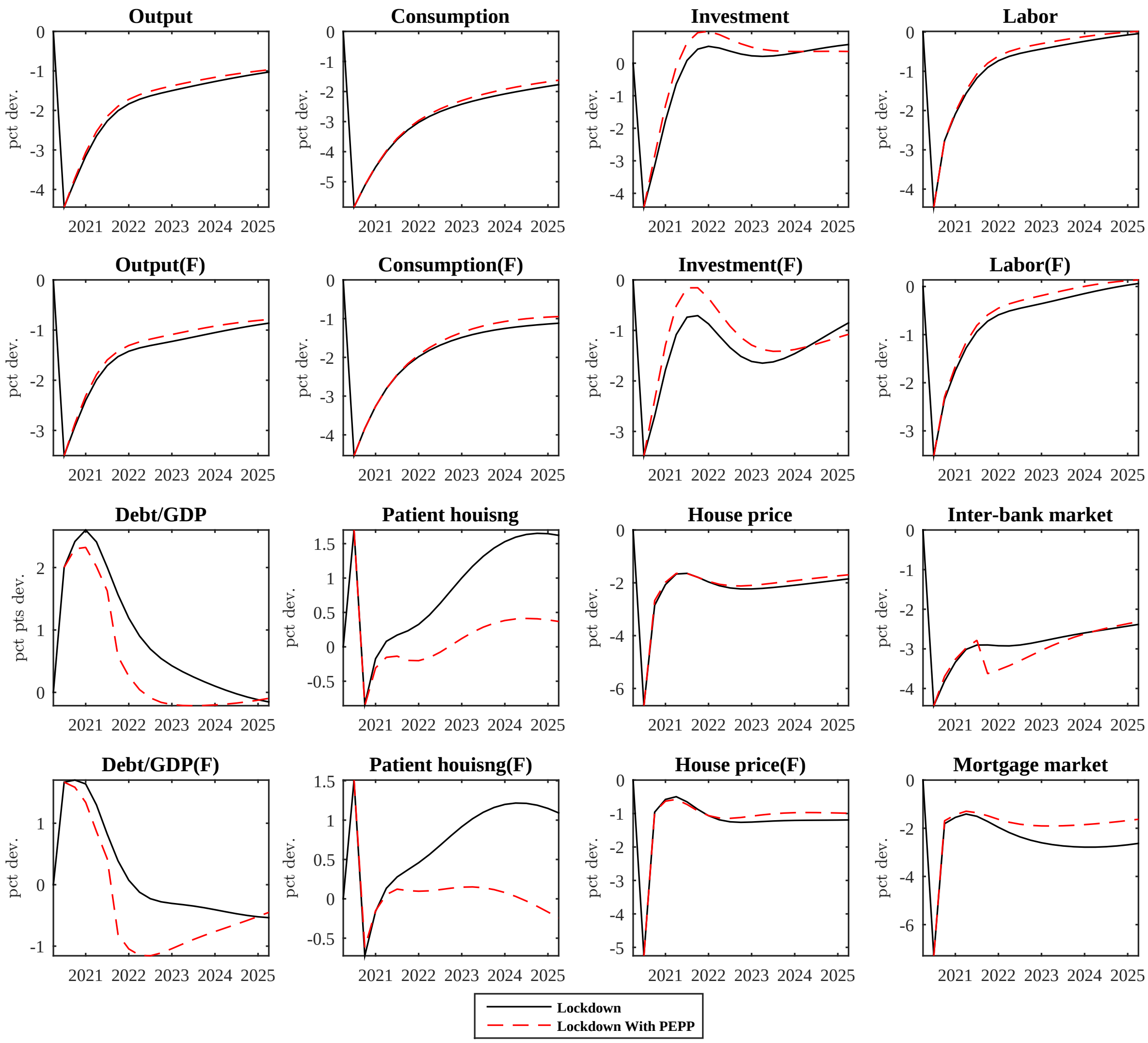

Figure 5: The Great Lockdown and the PEPP

When the path of the economy is figured out, it is possible to redo the procedure adding the PEPP. This program is started in 2020Q1 by injecting an envelope of 750 billion euro in addition to the 120 billion euro planned before the crisis. This is about 7.3% of euro area GDP. Given the initial ECB's announcement in March, the PEPP is a temporary asset purchase programme which will be stopped not before the end of 2020.[25] Based on this announcement, this paper assesses the impact of the PEPP package assuming that it will be concluded until the end of 2020. These purchase programs are applied to the model in the same fashion as in section 5.1.

[25]Just after the lockdown, various partial lockdowns and stimulus plans were implemented by governments, international organizations etc. For examle "On 4 June 2020 the ECB's Governing Council decided to increase the €750 billion envelope for the PEPP by €600 billion to a total of €1,350 billion" (ECB's website). These plans and other national or international interventions are not assessed in this paper.

Figure 5 presents the path of the economy in response to the Great Lockdown in 2020Q1 with and without the PEPP (starting at the end of 2020Q1). A host of channels are involved in shaping the dynamics of the model after the crisis, as follows. The crisis starts from the forced contraction of working hours. This straightforwardly causes a sharp decline in output. As a result, both wages and the return on capital fall. From there, three main channels influence the economy: the household balance sheet, bank portfolio and spread channels. In response to the wage reduction, households reduce consumption. Impatient households also decrease mortgage demand and housing. As a result, the house price drops, which in turn pushes down patient household wealth. In response, deposit supply falls. On the other hand, the drop in both mortgage supply and demand causes a decline in the demand side of the inter-bank market, which also mitigates demands in the deposit market. In this situation, the spread channel plays an important role. A lower return on loans motivates saving banks to get more involved in the bond market, which offers a higher return even if the default risk is now greater.

The next period after the shock is challenging. There is no other shock to the economy and the expectation of capital returns is high. This leads to a jump in capital investment, close to its level before the crisis. As a result, demands in the inter-bank and consequently in the deposit market rises, leading to a rise in the spread. At the same time, the household balance sheet expands, driving a surge in deposit issuance and mortgage demand. The latter further magnifies demand in the inter-bank market. The labor market is the first to recover. Output starts its recovery and increases gradually. The reason why output does not recover at the same pace as the labor market is consumption. Both the housing market, especially the behavior of the housing price which involves the LTV channel, and rigidity in the production sector prevent a fast recovery.

Figure 6 presents the response to the PEPP without and with the lockdown (only the net responses are presented). The PEPP activates the same channels and mechanisms similar to that of the APP as explained in section 5.1. For the sake of brevity, those mechanisms have not repeated here. Comparing the PEPP with and without the lockdown reveals four important points. First, in the presence of the lockdown, the PEPP stimulates the home country's output more than that of the foreign country. The reasons are twofold: i) the lockdown in the home country leads to a more severe recession than in the foreign country. As a result, the debt-to-GDP ratio is higher in the home country, ii) the initial conditions at the end of 2019. These two reasons provokes the spread and portfolio balancing channels to perform better in the home country. Second, the PEPP encourages the union mortgage market, however, the lockdown undermines its impact. The reason is originated in the nature of the crisis: the lockdown first weakens the advantageous impact of the PEPP on the labor market, squeezing the household balance sheet. As a result, the impatient households are less motivated to buy houses during the crisis.

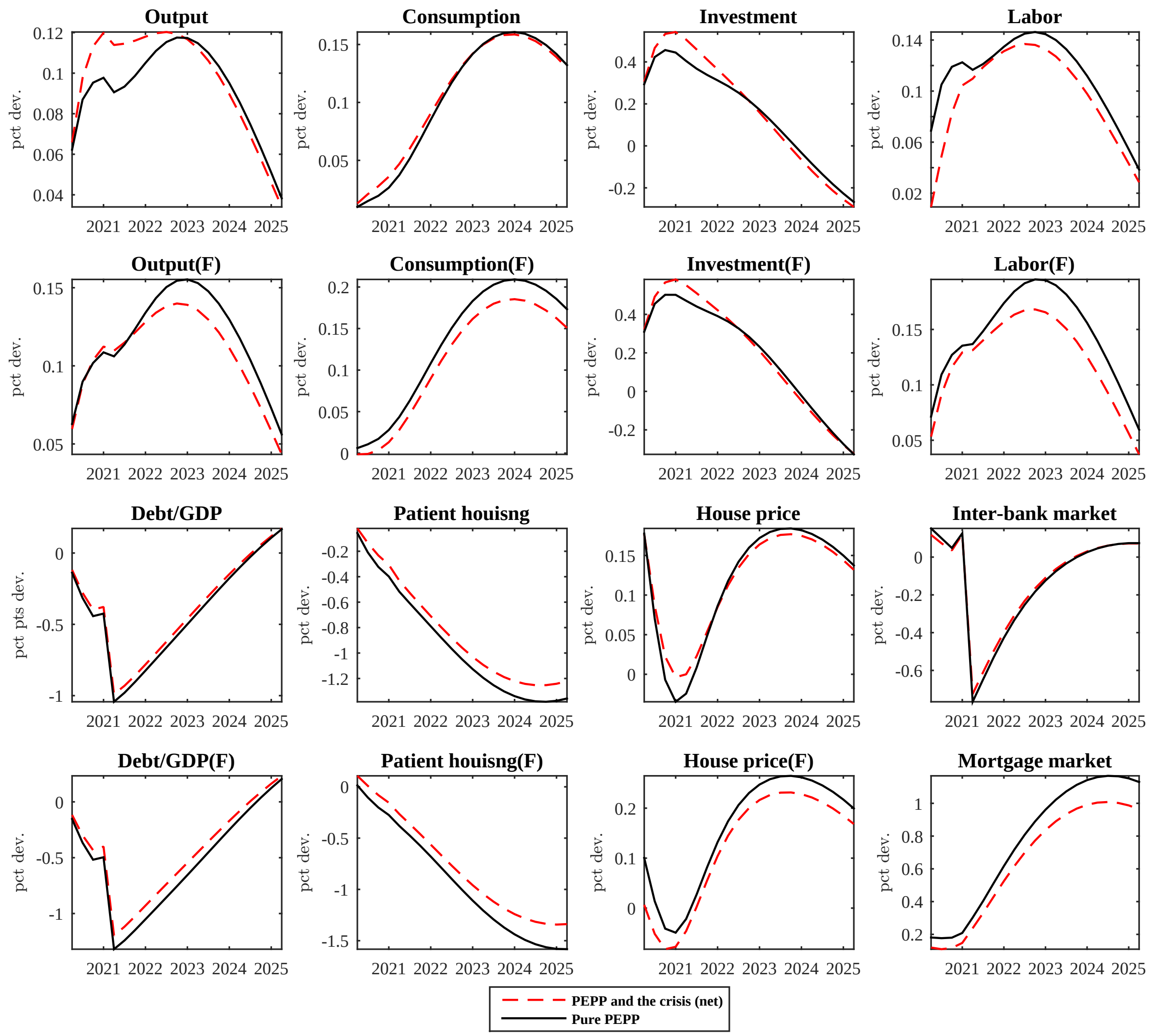

Figure 6: The Great Lockdown and the impact of the ECB's Pandemic Emergency Purchase Programme.

Third, the PEPP helps the inter-bank market under the portfolio balance channel. However, the saving banks retake more bonds, leading to an increase in debt to GDP in both countries immediately after the end of the program. This illustrates that in such a crisis impact of a prematurely ended program can be worst than the crisis itself on the inter-bank market. Forth, The results show the PEPP only has a partial effect on output and recovery. The reason is that the PEPP is most effective on the financial, bond and credit markets but cannot stimulate consumption, which is one of the main drivers of output with a share of about 65%. This has an important policy implication: quantitative easing in the form of asset purchases is not sufficient in such a crisis to accelerate a recovery. In other words, more actions, e.g. timely targeted fiscal policies, are needed to stimulate the demand side.

Another noteworthy point evidenced empirically in Rahal (2016) is that the response of the housing market, namely the house price, to an unconventional monetary policy is positive, persistent and at its maximum a few periods following the shock. The PEPP pushes the patient housing down by providing mortgage to impatient households.

6 Welfare analysis

This section computes the welfare effect of the crisis and the ECB's asset purchase programs investigated in the previous section. To present the results more intuitively, the welfare effects $\Xi^i, \quad i = P, I$ for patient and impatient households are collected as changes in terms of consumption equivalents, as follows

$$\sum_{t=0}^{\infty} \beta_i^t u((1-\Xi^i)c_t^i, o_t^i, h_t^i) = \sum_{t=0}^{\infty} \beta_i^t u(c^i, o^i, h^i), \quad i = P, I \tag{6.1}$$

$$\Xi = \frac{1}{c}(c^P \Xi^P + c^I \Xi^I) \tag{6.2}$$

Ξ is the total/social welfare effect which is the weighted average of patient and impatient welfare effects based on their consumption at the steady state. The interpretation of the welfare effect is as follows. If it is positive, this means that the household is better off, i.e. a welfare gain, and if it is negative, the household is worse off, i.e. a welfare loss.

Table 5: Welfare effects of the APP 2015Q1-2019Q4 (%)

	5 years		**Lifetime**	
	I	II	I	II
APP	0.32(0.44)*	0.29(0.51)	0.0651(0.0655)	0.0628(0.0725)
APP with the crisis (Net)	0.57(0.66)	0.53(0.74)	0.112(0.119)	0.112(0.124)

*Values in parentheses belong to the foreign country. I: Base model, II: Base model with household default risks.

Table 5 presents the welfare effects of scenarios described in section 5.1 for five years and the lifetime (250 periods) in two models: the base model (I) and the base model along with the risk of household default (II). There are three important points that should be investigated.

The first point is that the welfare gain of the APP during the crisis for the both countries is roughly one and a half times larger than that of the APP alone. The second point is that the foreign country gains more welfare during the APP in all scenarios. The reason for both conclusions above lies in the link between the performance of asset purchases and the debt-to-GDP channel, explained in section 5.1. The third point is that accounting for a household default risk has various impacts on welfare depending on the initial situation of each country: by accounting for a household default risk, the welfare gain is boosted in the foreign country and marginally reduced in the home country. The reason lies in the spread and other financial channels, illustrated in section 4.2.

Table 6 presents the welfare effects of the PEPP and the Great Lockdown described in

Table 6: Welfare effects of the PEPP and the Great Lockdown 2020 (%)

	5 years		**Lifetime**	
	Home	Foreign	Home	Foreign
PEPP	0.089	0.112	0.0145	0.0149
The Great Lockdown	−1.441	−0.740	−0.697	−0.555
PEPP with the crisis (Net)	0.091	0.088	0.0170	0.0129

section 5.2 for a 5-year period and the lifetime (250 periods). In addition to the three points mentioned above, table 6 illustrate three other points. First, the impact of the lockdown and the covid-19 crisis persists for a long time. It is weakened over time , for example about 50% for home country, but the welfare losses calculated for the lifetime still shows a high number. This proves the severity of such a crisis. Second, the comparison between results in the short and the long term for the PEPP reveals that the welfare gain of an asset purchase program is skewed left and does not endure for long; the welfare gain tends to be insignificant over the lifetime. This point is more intuitive if we compare the short-run and long-run welfare effects of the crisis and the PEPP. The welfare effect of the crisis persists, but the PEPP improves welfare only over the short term at the beginning. As a result from the long-term welfare perspective, limited asset purchase programs cannot achieve their objective and therefore they should be extended until the covid-19 crisis phase is over. Third, the lockdown weakens the PEPP's welfare gain of the foreign country. The reason is that, as it is shown in figure 6, the lockdown abates the impact of the PEPP on consumption, labor and housing market in the foreign country.

7 Conclusion

This paper builds a two-country model of a monetary union in the presence of heterogeneous households, housing, the credit market and household default risk. The main aim is to study the interaction between housing and unconventional monetary policy. The ECB's asset purchases are studied from 2015 to the Great Lockdown in 2020. This paper shows that macro-housing channels play an important role in amplifying the effects of shocks, notably on the real economy, by linking financial and households' balance sheets. These channels also impact bank portfolios and can therefore propagate or mitigate financial shocks. This paper helps to illustrate precisely the transfer of central bank policies to the economy. This transfer is more significant at the onset of a crisis when policy-makers are willing to combine expansionary monetary and fiscal policies; or when a sector of the economy is the focus of the policy. In addition, this paper indicates that in the recent crisis even though the PEPP helps the financial markets, it has minor impacts on the economic recovery as it cannot push up consumption. As a result, both an extended program as well as policy mixes, i.e. both monetary and fiscal actions, are required to manage such a crisis. Lastly, a welfare analysis assesses the impact of the crises and the performance of the ECB's asset purchase plans over 2015Q1-2020Q4.

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