EAGLE-FLI

A model for the macroeconomic analysis of banking sector and financial frictions in the euro area*

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Abstract

We incorporate financial linkages in EAGLE, a New Keynesian multi-country dynamic general equilibrium model of the Euro area by including financial frictions and country-specific banking sectors. In this new version, termed EAGLE-FLI (Euro Area and GLobal Economy with Financial Linkages), banks collect deposits from domestic households and cross-country interbank market and raise capital to finance loans issued to domestic households and firms. In order to borrow from local (regional) banks, both households and firms use domestic real estate as a collateral. These features – together with the full characterization of trade balance and real exchange rate dynamics and with a rich array of financial shocks – allow to properly assess domestic and cross-country macroeconomic effects of financial shocks.

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Non-technical Summary

The recent financial and banking crises, the long phase of economic stagnation and extremely low inflation, the large debate on the implied policy responses**,** in particular by central banks, have widely increase the relevance of domestic and cross-country financial factors for the macroeconomic performance of a monetary union such as the Euro area. Persistent and large heterogeneity in regional financial and banking factors can make difficult for the common monetary policy to guarantee macroeconomic stability of the union and call for country-specific macroprudential policies to favor financial stability at country and, hence, union levels. As such, understanding the role of country-specific structural financial features, the interaction among each other and their effect on the transmission mechanism of monetary policy is crucial for proper analysis of the stabilization issues and the assessment of the appropriate policy responses in the euro area in the aftermath of the recent crisis.

To tackle such issues we enrich a multi-country model of the Euro area called EAGLE (Euro Area and Global Economy) model, with financial frictions, banking sectors and a cross-country interbank market. This paper describes this new setup and its usefulness for various policy analyses by describing in detail the new features of the model and by illustrating the macroeconomic effects of the financial shocks. This version of the model is labelled EAGLE-FLI (Euro Area and Global Economy with Financial LInkages).

The original EAGLE model is a large-scale microfounded model constructed for the analysis of spillovers and macroeconomic interdependence across the different countries of the Euro area, as well as between them and other countries outside the monetary union. The open economy version of the New Keynesian paradigm constitutes EAGLE's theoretical kernel and guarantees a nontrivial role for monetary, exchange rate, fiscal and structural policy measures. The microfoundations of the model together with its rich structure allows for a quantitative analysis in a theoretically coherent and fully consistent model setup, clearly spelling out the policy implications.

New EAGLE features are the following ones. First, a microfounded banking sector in each of the four regions of the model is included. The banking sector collects deposits from savers, raises capital subject to a regulatory requirement, borrows and lends to domestic households and entrepreneurs and in the cross-country interbank market. Second, a fraction of households and entrepreneurs borrow from domestic banks by using local real estate as collateral. Third, the

model is enriched with financial shocks (to the loan-to-value ratio, to the amount of resources that banks lend in the interbank market in the long run, to the banks' capital requirement).

1 Introduction

The recent financial and banking crises, the long phase of economic stagnation and extremely low inflation, the large debate on the implied policy responses**,** in particular by central banks, have widely increase the relevance of domestic and cross-country financial factors for the macroeconomic performance of a monetary union such as the Euro area. Persistent and large heterogeneity in cross-regional financial and banking factors can make difficult for the common monetary policy to guarantee macroeconomic stability of the union and call for country-specific macroprudential policies to favor financial stability at country and, hence, union levels. As such, understanding the role of country-specific structural financial features, the interaction among each other and their effect on the transmission mechanism of monetary policy is crucial for proper analysis of the stabilization issues and the assessment of the appropriate policy responses in the euro area in the aftermath of the recent crisis.

To tackle such issues we enrich a multi-country model of the Euro area called EAGLE (Euro Area and Global Economy) model (see Gomes, Jacquinot and Pisani 2010, 2012) with financial frictions, banking sectors and a cross-country interbank market. This paper describes this new setup and its usefulness for various policy analyses by describing in detail the new features of the model and by illustrating the macroeconomic effects of the financial shocks. This version of the model is labelled EAGLE-FLI (Euro Area and Global Economy with Financial LInkages)[1]

The original EAGLE model is a large-scale microfounded model for the analysis of spillovers and macroeconomic interdependence across the different countries belonging to the EA and between them and other countries outside the monetary union. The open economy version of the New Keynesian paradigm, so called New Open Economy Macroeconomics framework, constitutes EAGLE's theoretical kernel and guarantees a nontrivial role for monetary, exchange rate, fiscal and structural policy measures. The microfoundations of the model together with its rich structure allows for a quantitative analysis in a theoretically coherent and fully consistent model setup, clearly spelling out the policy implications.[2]

EAGLE-FLI adds the following features to the original EAGLE framework. First, a micro-

[1] Jointly developed by staff of Bank of Portugal, Bank of Italy, Croatian National Bank and European Central Bank, EAGLE-FLI is a project of the EAGLE Network which is a network under the auspices of the Working Group on Econometric Modeling of the European System of Central Banks.

[2] The EAGLE setup builds on the New Area Wide Model (NAWM, Coenen, McAdam and Straub, 2008). See also the IMF's Global Economy Model (GEM, Laxton and Pesenti, 2003 and Pesenti, 2008), the Bank of Canada's version of GEM (Lalonde and Muir, 2007), the Federal Reserve Board's SIGMA (Erceg, Guerrieri and Gust, 2006), the European Commission's QUEST (Ratto, Roeger and in't Veld, 2009), and IMF's Global Integrated Monetary Fiscal Model (GIMF, Kumhof and Laxton, 2007).

founded banking sector in each of the four regions of the model is included. The bank collects deposits from a fraction of domestic households (the "savers"), borrows and lends in the cross-country interbank market, raises capital and lends to a fraction of domestic households (the "savers") and entrepreneurs. The bank is subject to a regulatory capital requirement. Second, borrowing by households and entrepreneurs is against collateral, namely local real estate. Third, we enrich the model with a set of financial shocks, such as shocks to the loan-to-value (LTV) ratio, amount of resources that banks desire to lend in the interbank market, bank capital requirement.

The EAGLE-FLI setup builds on several existing contributions. The distinction between borrowers, entrepreneurs and savers follows Iacoviello (2005). The banking sector is akin to the one in Iacoviello (2014). For the capital requirement ratio, we follow Kollmann (2013) and Kollmann, Ratto, and Roeger (2013), that consider the case of a global bank lending domestically and abroad. Brzoza-Brzezina, Kolasa, and Makarski (2013) develop a monetary union model of the EA featuring two regional banking sectors. Lombardo and McAdam (2012) estimate a model of the euro area with financial frictions. Guerrieri, Iacoviello, and Minetti (2012) consider a two-region model calibrated to the euro area featuring regional banks and sovereign debt default. Differently from these contributions, we introduce the banking sector in a large-scale open-economy New Keynesian dynamic general equilibrium model. As such, the model includes features needed for the quantitative assessment of cross-country financial and banking spillovers in a monetary union.

The paper is organized as follows. Section 2 shows the setup of the banking and financial sectors. Section 3 reports the calibration. Section 4 contains the results of simulating financial shocks. Section 5 concludes.

2 The model

In this section we report the novel features that characterize the EAGLE-FLI setup.[3] We outline the behavior of banks, savers, borrowers, entrepreneurs and report the related market clearing conditions.

The model features the world economy, whose size is normalized to one. It consists of four blocs (representing a country or a region). The size of each bloc measures the share of resident households and domestic sector-specific firms, both defined over a continuum of mass s. We

[3]For a brief description of the original EAGLE setup see the Appendix. For a detailed description see Gomes, Jacquinot, and Pisani (2010).

assume that two of the blocs, labelled Home (H) and rest of the EA (REA), are members of a monetary union, the Euro area (EA). As such, they share the monetary policy authority and the nominal exchange rates against the other two blocs, assumed to represent the US and the rest of the world (RW).

In what follows we focus on a description of the H bloc of the EA. We describe the banking sector, households' behavior, monetary authority. We end the section by detailing the market clearing conditions. Other blocs are similar, so we do not report the related equations to save on space. Specifically, the REA bloc has the same setup as H block. The US and RW blocks differ from those of the EA only because their banking sectors do not lend neither each other nor to EA banking sectors.

2.1 The banking sector

Similar to Kollmann (2013), we postulate the existence of the representative banking sector (the "bank"). Its size (as share of H population) is $0 < \omega_B < 1$. It acts under perfect competition and, hence maximizes profits taking interest rates as given and choosing the optimal amount of assets and liabilities. The banking sector intermediates funds between agents that cannot directly lend and borrow to each other (this is a crucial assumption for including the banking sector in a meaningful way in the model). The bank finances loans to the domestic impatient households (the "borrowers"), to domestic entrepreneurs through deposits (of domestic patient households) and capital. Moreover, the bank takes a position in the (cross-country) interbank market.

Utility. The lifetime utility function of the representative bank is defined in terms of real dividends:

$$E_t \sum_{k=0}^{\infty} \left(\beta^B\right)^k \frac{1}{1-\sigma} \left(\frac{DIV^B_{t+k}}{P^C_{t+k}} \right)^{1-\sigma} \tag{1}$$

where E is the expectation operator, $0 < \beta^B < 1$ is the discount factor, $1/\sigma > 0$ is the intertemporal elasticity of substitution, DIV^B represents nominal dividends from banking intermediation activity and P^C is the domestic consumption deflator.

The budget constraint. Deposits, loans, and the position in the interbank market are all defined as one-period euro-denominated nominal assets and liabilities. They enter the following

budget constraint (expressed in nominal terms):

$$\begin{aligned} DIV_t^B &= -L_t + R_{t-1}^L L_{t-1} - L_t^{IB} + R_{t-1}^{IB} L_{t-1}^{IB} \\ &\quad + D_t^{Supply} - R_{t-1}^D D_{t-1}^{Supply} \\ &\quad - P_t^C \Gamma_{IB,t} - P_t^C \Gamma_{X,t} \end{aligned} \tag{2}$$

where L denotes the amount of loans granted to domestic entrepreneurs and "borrowers" at the gross interest rate R^L, L^{IB} is the amount of loans granted to the REA banking sector in EA interbank market at the gross interest rate R^{IB}, D^{Supply} denotes the amount of deposits collected on which the gross interest rate R^D is paid. The terms $\Gamma_{IB,t}$ and $\Gamma_{X,t}$ are costs the banking sector faces when adjusting the position in the interbank market and the excess bank capital, respectively. They will be defined below.

The interbank market. The H bank can borrow from or lend to the REA bank in the EA interbank market, subject to the following adjustment cost:

$$\Gamma_{IB} \equiv \frac{\gamma_{IB}}{2} \left(l_t^{IB} - \frac{\kappa^{IB} \overline{p}^Y \overline{Y}}{\omega_B} \right)^2 \tag{3}$$

where $\gamma_{IB} > 0$ is a parameter and $l_t^{IB} \equiv L_t^{IB}/P_t^C$ is the interbank loan granted by this bank expressed in consumption units (real terms). The adjustment cost introduces a wedge between the interest rate on interbank loans and the interest rate on deposits. The parameters $\overline{p}^Y$ and $\bar{Y}$ represent the steady-state output deflator and real output, respectively ($\overline{p}^Y \bar{Y} \equiv \overline{P}^Y \overline{Y/P}^C$). The parameter κ^{IB} defined as:

$$\kappa_{IB} \equiv \frac{\omega_B \bar{l}_{IB}}{\overline{p}^Y \overline{Y}} \tag{4}$$

is the steady-state interbank loan-to-GDP ratio.

The interbank market is formalized in a rather simple way. The model represents a cashless economy (see Woodford, 1998) so we abstract from money and, hence, from interbank liquidity as well. However, the introduction of this market allows us to evaluate in the model cross-country spillovers directly associated with a bank's behavior towards the other representative bank. This is relevant in the light of the recent euro area economic history, characterized by relevant changes in the amount of cross-country interbank lending. In particular, introducing the interbank market allows to introduce a bank-specific shock by exogenously shocking the parameter κ_{IB}. This can

be interpreted as a change in the long-run "desired"amount of interbank lending, that may be related to factors not formalized such as changes in banks portfolio choices due to changes in liquidity needs or attitude toward risk.

Capital requirement. We assume the bank faces a regulatory capital requirement, i.e., its period t capital

$$K_t^B = L_t - D_t^{Supply} + L_t^{IB} \tag{5}$$

should not be less than a (possibly time-varying) fraction $\Upsilon_{K,t}$ $(0 < \Upsilon_{K,t} < 1)$ of its loans in the same period to domestic households and entrepreneurs, L_t.[4]Define excess bank capital, at the end of period t, as:

$$X_t \equiv (1 - \Upsilon_{K,t})L_t - D_t^{Supply} + L_t^{IB} \tag{6}$$

We assume it is costly for the bank to deviate from the long-run (steady-state) value of excess bank capital, according to the following quadratic function expressed in consumption units:[5]

$$\Gamma_X \equiv \frac{\gamma_X}{2}\left(x_t - \bar{x}\right)^2 \tag{7}$$

where $\gamma_X > 0$ is a parameter, $x_t \equiv X_t/P_t^C$ and $\bar{x}$ the corresponding steady-state value. This adjustment cost introduce a wedge between the interest rate on domestic loans and the interest rate on deposits.

First order conditions. The representative bank maximizes lifetime utility (1) subject to their budget constraint (2) and the cost from deviating from the capital requirement (7) (and excess bank capital definition (6)) with respect to dividends, deposit supply, loans supply and interbank position. This implies the following first order conditions:

- marginal utility of dividends

$$\Lambda_t^B = \left(\frac{DIV_t}{P_t^C}\right)^{-\sigma}\frac{1}{P_t^C} \tag{8}$$

- deposit supply

$$\Lambda_t^B = \beta^B E_t\left[\Lambda_{t+1}^B R_t^D\right] - \Lambda_t^B \gamma_X\left(x_t - \bar{x}\right) \tag{9}$$

[4]Bank capital requirements can limit moral hazard in the presence of informational frictions and deposit insurance. We do not model this issue and take the capital requirement as given. Moreover, for simplicity, we assume that interbank loans are not subject to the capital requirement.

[5]In the steady state equilibrium the capital requirement is satisfied, thus $X = L - D^{Supply} + L^{IB} - \Upsilon_K L = K^B - \Upsilon_K L \geq 0$.

- loans supply

$$\Lambda_t^B = \beta^B E_t \left[\Lambda_{t+1}^B R_t^L\right] - \Lambda_t^B \gamma_X (1 - \Upsilon_K)(x_t - \bar{x}) \tag{10}$$

- interbank loan

$$\Lambda_t^B = \beta^B E_t \left[\Lambda_{t+1}^B R_t^{IB}\right] - \Lambda_t^B \gamma_{IB} (l_t^{IB} - \frac{\kappa^{IB} \overline{p}^Y \overline{Y}}{\omega_B}) \tag{11}$$

2.2 Households

The Home economy is populated by a continuum of two types of households: patient ("savers") and impatient ("borrowers"). I-type households (indexed by i) are patient while J-type (indexed by j) are impatient households. The savers are a fraction $(1 - \omega_J - \omega_E - \omega_B)$ of the H population, where ω_J, ω_E $(0 < \omega_J, \omega_E < 1)$ are the shares of impatient households and entrepreneurs in the H population, respectively. For each type, households have same preferences, budget constraint and initial asset positions. As such, they make the same optimal choices and it is possible to assume a representative patient household and a representative impatient household (there is also a representative entrepreneur, as reported in Section 2.3). These two types of households differ in terms of their discount factors, whereby patient households discount the future at a lower rate than impatient households. As a consequence, in equilibrium, impatient households are net borrowers while patient households are net lenders *vis-à-vis* a domestic bank.[6] Both types of households consume and work. Savers have access to multiple financial assets, constrained households borrow from the domestic banking sector.

Patient household ("Saver")

Utility. The representative patient household, labelled "saver", gets utility from consumption of the non-durable composite good, C_t (subject to external habit formation) and housing services H_t and gets disutility from working N_t:

$$E_t \left[\sum_{k=0}^{\infty} (\beta^I)^k \left(\frac{1-\kappa}{1-\sigma}\left(\frac{C_{I,t+k} - \kappa C_{I,t+k-1}}{1-\kappa}\right)^{1-\sigma} + \iota_I \ln H_{I,t+k}(i) - \frac{1}{1+\zeta} N_{I,t+k}^{1+\zeta}\right)\right] \tag{12}$$

where β^I $(0 < \beta^I < 1)$ is the discount rate, κ $(0 \leq \kappa \leq 1)$ measures the degree of external habit formation in consumption, σ $(\sigma > 0)$ denotes the inverse of the intertemporal elasticity of substitution, $\iota_I > 0$ is a parameter for utility from housing services and ζ $(\zeta > 0)$ is the inverse of the elasticity of work effort with respect to the real wage (Frisch elasticity).

[6] For discount factor heterogeneity, see also Iacoviello (2005).

Budget constraint. The patient household provides work to firms in the two intermediate goods production sectors under monopolistic competition and set wages $W_{I,t}$ in a staggered way, *à la* Calvo. She holds positions in euro-denominated domestic sovereign bonds, in internationally traded US dollar-denominated bonds and euro-denominated bonds (the last assumption holds only for the two EA blocs). She also deposits in the domestic bank. The nominal aggregate budget constraint is:

$$\begin{aligned} & D_t^{Dem} - R_{t-1}^D D_{t-1}^{Dem} + B_{I,t} - B_{I,t-1}R_{t-1} + B_{I,t}^{EA} - B_{I,t-1}^{EA}R_{t-1} \\ & + S_t^{H,US} B_{US,t} - S_t^{H,US} B_{US,t-1} R_{t-1}^{US} \\ = \; & (1 - \tau_{N,t} - \tau_{W_h,t}) W_{I,t} N_{I,t} + (1 - \tau_{D,t}) DIV_t^F - Q_t^H (H_{I,t} - (1-\delta_H) H_{I,t-1}) \\ & - (1 + \tau_{C,t}) P_t^C C_{I,t} - P_t^C \Gamma_{DH} + TR_t - T_t \end{aligned} \tag{13}$$

where D^{Dem} is demand for bank deposits; $B_{I,t}$ is the position in the domestic government bonds, traded only domestically between patient household and the government and paying the EA (gross) monetary policy rate R; B_I^{EA} is the position in the euro-denominated bond, traded between EA patient households and paying the monetary policy rate EA rate R; B_{US} is holdings of bonds denominated in US dollars, paying the gross interest rate R_t^{US}, set by the US central bank, and converted in euro currency by the nominal exchange rate between euro and the US dollar $S_t^{H,US}$ (euro amount *per* unit of US dollar).[7] For income, $W_{I,t}N_{I,t}$ is labor income (W is nominal wage, while $0 < \tau_{N,t}$,$\tau_{W_h,t} < 1$ represent tax rates on labor and payrolls); DIV^F is income from ownership of domestic firms (other than banks) and $0 < \tau_D < 1$ the related tax rate. For expenditures, Q^H is the price of housing ($0 < \delta_H < 1$ is the depreciation rate of the housing stock, as housing is formalized as a durable good), $0 < \tau_{C,t} < 1$ is tax rate on (non-durable) consumption good, and Γ_{DH} is the cost of adjusting deposits (in terms of consumption units), which is defined as

$$\Gamma_{DH} \equiv \frac{\gamma_{DH}}{2} \left(d_t^{Dem} - \kappa^D \frac{\overline{p}^Y \overline{Y}}{1 - \omega_J - \omega_E - \omega_B} \right)^2 \tag{14}$$

where $d_t^{Dem} \equiv D_t^{Dem}/P_t^C$ is the demand for deposits expressed in "real " terms (domestic consumption units). Also:

$$\kappa^D \equiv \frac{(1 - \omega_J - \omega_E - \omega_B)\, \overline{d}^{Dem}}{\overline{p}^Y \overline{Y}} \tag{15}$$

[7] As standard in the literature, we add an adjustment cost on top of the interest rate paid by the US bond so to make the bond position (and, hence, the model) stationary. See the Appendix for details.

is the share of deposits in steady-state GDP, where $(1-\omega_J-\omega_E-\omega_B)\,\overline{d}^{Dem}$ are aggregate deposits and $\overline{p}^Y\overline{Y}$ is aggregate output, both computed in steady state. Finally, the terms TR and T represent (gross) *lump-sum* transfers and taxes. They are set, together with public spending and tax rates, by the domestic fiscal authority.

First order conditions. The household maximizes her lifetime utility subject to the budget constraint taking all prices but wages as given. Focusing on the new features of the model, namely housing and bank deposits, we obtain the following first order conditions (Λ_I is the marginal utility of consumption):

- marginal utility of consumption

$$\Lambda_{I,t}P_t^C(1+\tau_C)=\left(\frac{C_{I,t}-\kappa C_{I,t-1}}{1-\kappa}\right)^{-\sigma} \tag{16}$$

- deposits demand

$$\Lambda_{I,t}\left[1+\gamma_{DH}\left(d_t^{Dem}-\frac{\kappa^D\overline{p}^Y\overline{Y}}{1-\omega_J-\omega_E}\right)\right]=\beta_I E_t\left[\Lambda_{I,t+1}R_t^D\right] \tag{17}$$

- real estate demand

$$\Lambda_{I,t}Q_t^H=\frac{\iota}{H_{I,t}}+\beta^I E_t\left[\Lambda_{I,t+1}(1-\delta_H)Q_{t+1}^H\right] \tag{18}$$

The remaining first order conditions are standard and reported in the Appendix.

Impatient household ("borrower")

Utility. The representative impatient household represents a fraction ω_J of the H population. She discounts the future at a higher rate than patient household (and bank). This makes her, in equilibrium, borrower vis-à-vis the domestic bank. The impatient households lifetime utility function is:

$$E_t\left[\sum_{k=0}^{\infty}(\beta_J)^k\left(\frac{1-\kappa}{1-\sigma}\left(\frac{C_{J,t+k}-\kappa C_{J,t+k-1}}{1-\kappa}\right)^{1-\sigma}+\iota_J\ln H_{J,t+k}-\frac{1}{1+\zeta}N_{J,t+k}^{1+\zeta}\right)\right] \tag{19}$$

where $\beta_J<\beta_I$.

Budget constraint. The impatient household provides work to firms in the two intermediate goods production sectors under monopolistic competition and set wages $W_{J,t}$ in a staggered way, *à la* Calvo. The (nominal) budget constraint is:

$$\begin{aligned} & B_{J,t} - R_{t-1}^{L} B_{J,t-1} \\ = \; & (1 - \tau_N - \tau_{WH}) W_{J,t} N_{J,t} - (1 + \tau_C) P_t^C C_{J,t} - Q_t^H (H_{J,t} - (1 - \delta_H) H_{J,t-1}) \end{aligned} \tag{20}$$

where $B_{J,t} < 0$ is the amount of loans from domestic bank and R_t^L the is the interest rate.

Borrowing constraint. In equilibrium, the impatient household is a net borrower. To borrow funds, she needs a collateral, represented by the expected value of the housing stock. Therefore, she faces the following borrowing constraint:

$$-B_{J,t} R_t^L \leq V_{J,t} E_t \left[Q_{t+1}^H H_{J,t} \right] \tag{21}$$

where $0 < V_{J,t} < 1$ is the (possibly time-varying) loan-to-value ratio. The borrowing constraint is consistent with standard lending criteria used in the mortgage market, which limit the amount lent to a fraction of the value of the asset.

First order conditions. The impatient household maximizes utility with respect to consumption of nondurables, housing and loans subject to the budget constraint and the borrowing constraint and taking all prices, but wages, as given. The reason is that the impatient household supplies labor under monopolistic competition. As such, she optimally sets her nominal wage taking labor demand by firms into account. The borrowing constraint is assumed to hold with equality (see Iacoviello, 2005). Focusing on the new features of the model, we obtain the following first order conditions:

- marginal utility of consumption

$$\Lambda_{J,t} P_t^C (1 + \tau_C) = \left(\frac{C_{J,t} - \kappa C_{J,t-1}}{1 - \kappa} \right)^{-\sigma} \tag{22}$$

- loan demand

$$\Lambda_{J,t} = R_t^L \Lambda_{JC,t} + \beta_J E_t \left[\Lambda_{J,t+1} R_t^L \right] \tag{23}$$

- real estate demand

$$\Lambda_{J,t}Q_t^H = \frac{\iota}{H_{J,t}} + \beta_J E_t\left[\Lambda_{J,t+1}(1-\delta_H)Q_{t+1}^H\right] + \Lambda_{JC,t}V_{J,t}E_t\left[Q_{t+1}^H\right] \tag{24}$$

where Λ_J is the Lagrange multiplier of the budget constraint and $\Lambda_{JC,t}$ is the Lagrange multiplier of the borrowing constraint. Note that the presence of the borrowing constraint affects the optimal choices of borrowing and housing services (equations 23 and 24, respectively). Both the Euler and the housing demand equations differ from the corresponding patient household' formulations because of the presence of the Lagrange multiplier on the borrowing constraint. The multiplier equals the increase in lifetime utility that would stem from borrowing R^L euros, consuming or investing the proceeds, and reducing consumption by an appropriate amount the following period.

2.3 Entrepreneur

Utility. The representative entrepreneur represents a fraction ω_E of the H population. She maximizes the utility of a lifetime consumption represented by:

$$E_t\sum_{k=0}^{\infty}(\beta_E)^k\left(\frac{1-\kappa}{1-\sigma}\left(\frac{C_{E,t+k}-\kappa C_{E,t+k-1}}{1-\kappa}\right)^{(1-\sigma)}\right) \tag{25}$$

Budget constraint. The entrepreneur owns the physical capital stock and part of the aggregate (regional) stock of real estate. Both are rented in a competitive market to firms operating in the domestic intermediate sectors. Entrepreneurs can borrow funds from domestic banks. The investment in physical capital is subject to adjustment costs (Γ_I), reported in the capital accumulation law (see the Appendix). The budget constraint reads as:

$$\begin{aligned} B_{E,t} - R_{t-1}^L B_{E,t-1} &= Rent_t H_{E,t-1} + (1-\tau_K)\left(R_{K,t}u_t - \Gamma_u(u_t)P_t^I\right)K_{E,t-1} + \tau_{K,t}\delta P_t^I K_{E,t} \\ &\quad -Q_t^H\left(H_{E,t} - (1-\delta^H)H_{E,t-1}\right) - (1+\tau_C)P_t^C C_{E,t} - P_t^I I_{E,t} \end{aligned} \tag{26}$$

where $B^E < 0$ is the amount of loans from domestic bank, *Rent* and $R_{K,t}$ are the rental rates of real estate H_E and physical capital K_E to firms in the intermediate sector, respectively. The variable u stands for capital utilization and Γ_u stands for the respective adjustment cost. The variable $\tau_{K,t}$ ($0 < \tau_K < 1$) is the tax rate on physical capital, set by the domestic fiscal

authority. The parameters δ, δ^H $(0 < \delta, \delta^H < 1)$ are the depreciation rates of capital and real estate, respectively. Finally, the variable I_E is the investment in physical capital, whose price is P^I.

Borrowing constraint. The entrepreneur borrows funds B^E from the domestic banking sector using the owned real estate as collateral:

$$-R_t^L B_{E,t} \leq V_{E,t} E_t \left[Q_{t+1}^H H_{E,t} \right] \tag{27}$$

where $0 < V_{E,t} < 1$ is the (possibly time-varying) entrepreneur's loan-to-value ratio.

First order conditions. The entrepreneur maximizes her utility with respect consumption, physical capital, investment in physical capital and housing subject to the budget constraint and the borrowing constraint and taking prices as given. The novel first order conditions are:

- consumption of nondurables

$$\Lambda_{E,t} P_t^C (1 + \tau_C) = \left(\frac{C_{E,t} - \kappa C_{E,t-1}}{1 - \kappa} \right)^{-\sigma} \tag{28}$$

- real estate demand

$$\Lambda_{E,t} Q_t^H = \beta_E E_t \left[\Lambda_{E,t+1} Rent_{t+1} + \Lambda_{E,t+1} (1 - \delta_H) Q_{t+1}^H \right] + \Lambda_{EC,t} V_{E,t} E_t \left[Q_{t+1}^H \right] \tag{29}$$

- loan demand

$$\Lambda_{E,t} = R_t^L \Lambda_{EC,t} + \beta_E E_t \left[\Lambda_{E,t+1} R_t^L \right]. \tag{30}$$

where Λ_t^E is the Lagrange multiplier of the entrepreneurs' budget constraint and $\Lambda_{EC,t}$ is the Lagrange multiplier of the entrepreneurs' borrowing constraint. Like for impatient households, the equations for consumption and housing choice hold with the addition of the multiplier associated with the borrowing restriction. The borrowing constraint introduces a wedge between the price of the real estate and its rental rate. It can be considered as a tax on the demands for credit and real estate.

The remaining first order conditions with respect to investment, capital utilization and the law of motion for capital are rather standard and thus reported in the Appendix.

2.4 Firms

There are two types of firms. One type produces internationally tradable and nontradable intermediate goods. The other type produces nontraded final goods for consumption and investment purposes, using all intermediate goods as inputs.

Final good firms

Firms producing final nontradable goods are symmetric, act under perfect competition and use nontradable as well as domestic and imported tradable intermediate goods as inputs. The intermediate goods are assembled according to a constant elasticity of substitution (CES) technology. Final goods can be used both for private consumption and investment.

The setup of the final good firms mimics the one in the version of the EAGLE model without financial frictions and a banking sector.[8] The related equations are reported in the Appendix.

Intermediate good firms

There are firms producing tradable and nontradable intermediate goods (brands) under monopolistic competition regime. Each tradable brand is produced by a firm h belonging to the continuum of mass s^H ($h \in [0, s^H)$. Similarly, each nontradable brand is produced by a firm n, also defined over the continuum of mass s^N ($n \in [0, s^H)$. Since EAGLE-FLI introduces a new input in production compared to the original EAGLE model, we will be describe the intermediate goods sector setup in more detail.

Production technology. Each nontradable and tradable intermediate good, respectively n and h, is produced using a Cobb-Douglas technology with three inputs: physical capital rented from domestic entrepreneurs ($K_t^D(n)$ and $K_t^D(h)$); domestic labor ($N_t^D(n)$ and $N_t^D(h)$, each being an aggregate of both patient and impatient households labor services); real estate ($H_t^D(n)$ and $H_t^D(h)$) rented from domestic entrepreneurs

$$Y_t^{S,N}(n) = z_{N,t} K_t^D(n)^{\alpha_{KN}} H_t^D(n)^{\alpha_{HN}} N_t^D(n)^{1-\alpha_{KN}-\alpha_{HN}} \quad (31)$$

$$Y_t^{S,T}(h) = z_{T,t} K_t^D(h)^{\alpha_{KT}} H_t^D(h)^{\alpha_{HT}} N_t^D(h)^{1-\alpha_{KT}-\alpha_{HT}} \quad (32)$$

[8] For the details please see Gomes, Jacquinot and Pisani (2010, 2012).

where $0 < \alpha_{KN}, \alpha_{KT}, \alpha_{HN}, \alpha_{HT} < 1$ and $z_{N,t}$ and $z_{T,t}$ are sector-specific productivity shocks (they are identical across firms within each sector).[9]

Taking input prices as given, firms in each sector minimize total production costs subject to the respective production function, (equations 31 and 32). This yields the demand functions for each type of input which are rather standard and reported only in the Appendix.

Price setting. Each intermediate goods producing firm sells its differentiated output under monopolistic competition in the domestic and the foreign markets. The firm charges different prices in local currency at home and in each foreign region. There is sluggish price adjustment due to staggered price contracts *à la* Calvo (1983). Firm h in the intermediate tradable sector discriminates across countries, by invoicing and setting the price of its brand in the currency of the generic destination market. Hence, the local currency pricing assumption holds. For details on the price setting equations see Gomes, Jacquinot and Pisani (2010, 2012). The corresponding equations are reported in the Appendix.

2.5 Monetary authority

In the case of the EA, there exists a single monetary authority that targets a weighted (by regional size) average of regional (Home, H, and REA) annual consumer price inflation and real quarterly output growth:

$$\begin{aligned}\left(R_t^{EA}\right)^4 &= \phi_R^{EA}\left(R_{t-1}^{EA}\right)^4 + \left(1-\phi_R^{EA}\right)\left[\left(\overline{R}^{EA}\right)^4 + \phi_\Pi^{EA}\left(\Pi_{C,t}^{EA,4} - \overline{\Pi}^{EA,4}\right)\right] \\ &\quad + \phi_{gY}^{EA}\left(Y\mathrm{gr}_t^{EA} - 1\right) + \varepsilon_{R,t}^{EA} \end{aligned} \tag{33}$$

where $\overline{\Pi}^{EA,4}$ is the long-run (yearly) inflation target and the yearly inflation rate $\Pi_{C,t}^{EA,4}$ is defined as:

$$\Pi_{C,t}^{EA,4} \equiv \left(\Pi_{C,t}^{H,4}\right)^{\frac{s^H}{s^H+s^{REA}}} \left(\Pi_{C,t}^{REA,4}\right)^{\frac{s^{REA}}{s^H+s^{REA}}} \tag{34}$$

with:

$$\Pi_{C,t}^{H,4} \equiv \frac{P_{C,t}^H}{P_{C,t-4}^H}, \;\; \Pi_{C,t}^{REA,4} \equiv \frac{P_{C,t}^{REA}}{P_{C,t-4}^{REA}} \tag{35}$$

[9] In the case of the EA there is also a technology shock z_t, which is common to both sectors and regions.

and the EA output growth rate $Y_{gr,t}^{EA}$ is defined as:

$$Y_{gr,t}^{EA} \equiv \frac{Y_t^{EA}}{Y_{t-1}^{EA}} \equiv \frac{s^H Y_t^H + s^{REA} Y_t^{REA}}{s^H Y_{t-1}^H + s^{REA} Y_{t-1}^{REA}} \tag{36}$$

where Y_t^H and Y_t^{REA} represent total final real output in the H and REA regions, respectively. They are weighted by the corresponding sizes of the regions in the world economy.

2.6 Market clearing conditions

In this section, we report clearing conditions for the housing, loan, deposit, EA cross-country interbank markets. The remaining clearing conditions are reported in the Appendix.

- Housing market

  Households and entrepreneurs demand real estate, which is assumed to be nontradable across countries and in aggregate fixed supply $\bar{H}$:

  $$(1 - \omega_J - \omega_E) H_t^I + \omega_J H_t^J + \omega_E H_t^E = \bar{H} \tag{37}$$

  Entrepreneurs rent housing to firms producing intermediate tradable and nontradable goods:

  $$H_t^T + H_t^{NT} = \omega_E H_t^E \tag{38}$$

- Loan market

  Bankers supply loans to domestic entrepreneurs and impatient households:

  $$L_t + \omega_J B_t^J + \omega_E B_t^E = 0 \tag{39}$$

- Deposit market

  Patient households demand bank deposits to domestic banks:

  $$D_t^{Supply} = (1 - \omega_J)\, D_t^{Dem} \tag{40}$$

- EA cross-country interbank market

The two EA regional banks lend each other resources through the EA interbank market. The market clearing is:

$$s^H L_t^{IB,H} + s^{REA} L_t^{IB,REA} = 0 \tag{41}$$

where s^H and s^{REA} are respectively the sizes of Home and REA regions, $L^{IB,H}$ and $L^{IB,REA}$ are the positions of Home and REA regions, respectively.

2.7 Net foreign assets position and international relative prices

Home holdings of foreign bonds (that is, the Home economy's net foreign asset position), denominated in US dollars evolve according to:

$$B_{US,t} + \frac{L_t^{IB}}{S_t^{H,US}} = B_{US,t-1} R_{t-1}^{US} + \frac{R_{t-1}^{IB} L_{t-1}^{IB}}{S_t^{H,US}} + \frac{TB_t^H}{S_t^{H,US}} \tag{42}$$

where TB_t^H stands for the Homes trade balance and $S_t^{H,US}$ is the nominal exchange rate, measured as number of euro per US dollar. The Home trade balance is:

$$TB_t^H \equiv \sum_{CO \neq H} \frac{s^{CO}}{s^H} S_t^{H,CO} P_{X,t}^{H,CO} IM_t^{CO,H} - \sum_{CO \neq H} P_{IM,t}^{H,CO} IM_t^{H,CO} \tag{43}$$

where $S_t^{H,CO}$ is the nominal exchange rate (number of euros for unit of foreign currency), $IM_t^{CO,H}$ is Home exports ($P_{X,t}^{H,CO}$ is the corresponding price index in foreign currency), $IM_t^{H,CO}$ is Home imports ($P_{IM,t}^{H,CO}$ is the corresponding price index in euro terms).

The market clearing conditions, jointly with the budget constraints of the households, entrepreneurs, banking sector and the fiscal authority, imply the following aggregate resource constraint:

$$\begin{aligned} P_{Y,t} Y_t \quad = \quad & P_{C,t} C_t + P_{I,t} \left(I_t + \Gamma_u \left(u_t \right) K_t \right) + P_{G,t} G_t + \sum_{CO \neq H} \frac{s^{CO}}{s^H} S_t^{H,CO} P_{X,t}^{H,CO} IM_t^{CO,H} \\ & - \sum_{CO \neq H} P_{IM,t}^{H,CO} \left(IM_{C,t}^{H,CO} \frac{1 - \Gamma_{IM^C}^{H,CO} \left(IM_t^{C,CO} / Q_t^C \right)}{\Gamma_{IM^C}^{H,CO\dagger} \left(IM_t^{C,CO} / Q_t^C \right)} \right) \\ & - \sum_{CO \neq H} P_{IM,t}^{H,CO} \left(IM_{I,t}^{H,CO} \frac{1 - \Gamma_{IM^I}^{H,CO} \left(IM_t^{I,CO} / Q_t^I \right)}{\Gamma_{IM^I}^{H,CO\dagger} \left(IM_t^{I,CO} / Q_t^I \right)} \right) \end{aligned} \tag{44}$$

where aggregate consumption C_t is:

$$C_t = \omega_B C_t^B + (1 - \omega_J - \omega_E - \omega_B) C_{I,t} + \omega_J C_{J,t} + \omega_E C_t^E \tag{45}$$

with:

$$C_{B,t} \equiv div_t^B \equiv \frac{DIV_t^B}{P_t^C} \tag{46}$$

and $\Gamma_{IM^C}^{H,CO}$ is a (standard) adjustment costs on imports and $\Gamma_{IM^C}^{H,CO\dagger}$ is defined as (see the Appendix for more details):

$$\Gamma_{IM^C}^{H,CO\dagger}\left(\frac{IM_t^{C,CO}}{Q_t^C}\right) \equiv 1 - \Gamma_{IM^C}^{H,CO}\left(\frac{IM_t^{C,CO}}{Q_t^C}\right) - \left(\Gamma_{IM^C}^{H,CO}\left(\frac{IM_t^{C,CO}}{Q_t^C}\right)\right)' IM_t^C.$$

The Home bilateral terms of trade are defined as the domestic price of imports relative to the price of exports, both expressed in Home currency:

$$TOT_t^{H,CO} \equiv \frac{P_{IM,t}^{H,CO}}{S_t^{H,CO} P_{X,t}^{H,CO}} \tag{47}$$

The Home bilateral real exchange rate is defined as the CPI of country CO relative to the CPI of country H, both expressed in Home currency:

$$RER_t^{H,CO} \equiv \frac{S_t^{H,CO} P_{C,t}^{CO}}{P_{C,t}^H} \tag{48}$$

3 Calibration

Tables 1 to 9 summarize the (quarterly) calibration of the model. We calibrate the model to Germany (Home country), as in the standard EAGLE version, REA, US and RW. We set parameter values to match great ratios or we follow the empirical evidence and the existing literature on EAGLE, GEM and NAWM.

Table 3 reports the great ratios. National accounts data are taken from the European Commission AMECO database. We set region sizes to match the share of world GDP (IMF data). We calibrate the net foreign asset position of each economy to match the corresponding data.[10]

Table xxx reports banks' balance sheet, as a ratio to annualized GDP. Given the lack of available data on collateralized loans for other purposes but housing, we chose to match the

[10] Given the import shares, net foreign asset position and international interest rate, the steady-state trade balance and real exchange rate level endogenously adjust.

average share (in a period from 1997 to 2013) of total loans to non-financial corporations and to households in annual GDP, namely to 30 and 60 percent in Home country), respectively; 50 percent each in REA; and around 55 and 25 percent in the US and RW, respectively[11]. We assume that the steady-state (EA) interbank position is zero due to lack of reliable data for the euro area. Given the matched values for loans, the assumed interbank position, the capital requirement, and the assumed zero excess bank capital, we allow deposits to endogenously adjust consistently with the bank's balance sheet. The chosen calibration strategy emphasizes the role of banks loans and induces a broad interpretation of bank deposits, (given the absence of other financing sources such as bank bonds).

Table xxx reports the parameters related to financial frictions and banking sector. The impatient households' LTV ratio is set to 0.7 in both EA regions. The entrepreneurs' LTV ratio is set to 0.9. The chosen values allow us to match the bank loans-to-GDP ratios. The adjustment cost on excess bank capital is set to 0.001 in all blocs. The adjustment cost on deposits is set to 0.0001 in the EA while in the US and RW it is set to 0.6. The capital requirement parameter is set to 8 percent in the EA and the US, compatible with the BASEL III minimum requirement for total capital.

Table 1 reports preference and technology parameters. Preferences are assumed to be the same across household types and regions. We set the discount factor of patient households to 0.9926 (implying a steady-state annualized real interest rate of about 3 percent). The discount factor of impatient households, entrepreneurs and bankers are set to 0.96, 0.99 and 0.9926, respectively. Habit persistence parameter, the intertemporal elasticity of substitution and the Frisch elasticity are respectively set to 0.70, 1 and 0.50. We set quarterly depreciation rate of capital to be consistent with a 10 percent annual depreciation rate. The share of impatient households in each region is set to 0.30 while the share of entrepreneurs is set to 0.10.

On the production side, in the Cobb-Douglas production functions of tradable and non-tradable intermediate goods the bias towards capital is set to around 0.3 and the bias towards housing to 0.05. As for the final goods baskets, the degree of substitutability between domestic and imported tradables is higher than that between tradables and nontradables, consistent with existing literature (elasticities equal to 2.5 and 0.5, respectively).[12] The biases towards the trad-

[11]The source for outstanding amounts of the balance sheet item in the EA is the ECB Monetary and financial statistics, while for the US is the Board of Governors of the Federal Reserve System.

[12]Note that the short-run elasticity for imported goods is lower because of adjustment costs on imports. Numbers are consistent with Bayoumi, Laxton, and Pesenti (2004).

able bundle in the consumption and investment baskets are equal respectively to 0.45 and 0.75 in each region of the EA and respectively to 0.35 and 0.75 in the US and RW. The weight of domestic tradable goods in the consumption and investment tradable baskets is different across countries, to be coherent with multilateral import-to-GDP ratios.

Markups in the EA nontradables sector (a proxy for the services sector) and labor market are higher than the corresponding values in the US and RW (see Table 5). In all regions the markup in the tradables sector (a proxy for the manufacturing sector) has the same value and the markup in the nontradables sector is higher than that in the labor market.[13]

We set weights of bilateral imports (Table 7) to match the trade matrix reported in Table 8.[14]

Table 6 reports nominal and real rigidities. We set Calvo price parameters in the domestic tradables and nontradables sector to 0.92 (12.5 quarters) in the EA, consistently with estimates by Christoffel, Coenen, and Warne (2008) and Smets and Wouters (2003). Corresponding nominal rigidities outside the EA are equal to 0.75, implying an average frequency of adjustment equal to 4 quarters, in line with Faruqee, Laxton, and Muir (2007). Calvo wage parameters and price parameters in the export sector are equal to 0.75 in all the regions. The indexation parameters on prices and wages are equal respectively to 0.50 and 0.75, so to get sufficiently hump-shaped response of wages and price. For real rigidities, we set adjustment costs on investment changes to 6 in the EA and to 4 in the case of the US and RW; and adjustment costs on consumption and investment imports to 2 and 1, respectively.

Finally, Table 9 reports parameters in the monetary rules and fiscal rules. The interest rate reacts to the its lagged value (inertial component of the monetary policy), annual inflation and quarterly output growth. In the monetary union, monetary policy reacts to EA-wide variables. For fiscal rules, lump-sum taxes stabilize public debt. Steady-state ratios of government debt over output are equal to 2.40 in all the regions (0.6 in annual terms). Tax rates are set to be consistent with empirical evidence (see Coenen, McAdam, and Straub 2008), except for the tax rate on capital income to match the investment-to-output ratio.

[13]The chosen values are consistent with estimates from Martins, Scarpetta and Pilat (1996), suggesting that the degree of competition in the nontradable sector is lower than in the tradable sector. Also, these values are in line with other similar studies, such as Bayoumi, Laxton, and Pesenti (2004), Faruqee, Laxton, and Muir (2007) and Everaert and Schule (2008).

[14]The trade matrix is calibrated using Eurostat and IMF trade statistics.

4 Simulations

In what follows we report the effects of several shocks to show the main transmission channels operating in EAGLE-FLI. Specifically, we report a reduction in the EA monetary policy rate, an increase in the Home LTV ratio, an increase in the long-run amount of interbank lending by Home bank, a simultaneous increase in the capital requirement ratio in both Home and REA regions. The model is simulated under perfect foresight using DYNARE.

4.1 Reduction of the EA monetary policy rate

Figures 1a-1d show the implications of a monetary policy shock in the EA. The shock is such that there is an initial decline in the (annualized) short-term nominal interest rate of about 100 basis points.

Figure 1a reports the response of the banking sector variables. All bank choices are dictated by the no-arbitrage conditions implicitly given by their first order conditions with respect to the different financial assets. The lower monetary policy rate is transmitted to interest rates on bank loans and bank deposits, that decrease. Lending to domestic (impatient) households and entrepreneurs increase, financed by the increase in deposits (patient households smooth consumption increasing their saving). Also, bank capital falls. The Home bank decreases, to a rather small extent, its lending to REA bank through the interbank market.

Figure 1b reports the responses of borrowing and housing. In both regions, the impatient household and the entrepreneur increase their borrowing and their demand for housing, which they use as collateral. Firms operating in both the tradables and nontradables sectors increase their housing demand as well, to increase production. Higher demand by impatient household and entrepreneur induces the increase in the the housing price.

The impact of the shock on main macroeconomic variables (GDP, its components and CPI inflation) is, as expected, expansionary (Figure 1c). In particular, exports increase favored by the depreciation of the real exchange rate.[15] Imports increase as well, driven by the higher EA aggregate demand.

Finally, consumption by all households and labor increase (Figure 1d). Real wages of impatient and patient households increase, driven by the higher labor demand by domestic firms operating in the tradable and nontradables sectors.

[15] In all figures, an increase in the real exchange rate represents a depreciation, while an increase in the terms of trade represents a worsening.

Spillovers to the US and the RW are rather small. To save on space, we do not report them.

Overall, the banking sector transmits the monetary policy stimulus to the real side of the economy, favoring a increase in EA economic activity. The increase is rather symmetric across the two regions.

4.2 Increase in REA LTV ratio

Figures 2a-2d show the effects of an exogenous rise in the REA LTV ratio of entrepreneurs and impatient households (V_J and V_E in equations (21) and (27), respectively). In the initial period, it increases by 1 percentage point. Subsequently, it gradually returns to the steady state value (the persistence of the shock process is set to 0.90).

The increase in REA LTV induces an increase in domestic demand for loans, partially absorbed by the increase in the interest rate on loans (Figure 1a). The EA monetary policy rate increases only slightly, as the shock is only slightly expansionary in the EA and does not greatly affect EA CPI inflation. To finance the higher amount of loans, Home banks also increase demand for deposits, interbank borrowing and capital. As a result, interest rates on deposits and on interbank market increase. Banks rise capital to a relatively small amount, as it is relatively costly to deviate from the long-run value for bank capital.

The increase in the LTV ratio implies that households and firms can increase their borrowing, given value of the collateral (Figure 2b). They also increase demand for real estate, driving up prices. The increase in the value of collateral amplifies the initial shock, favoring borrowing.

The increase in aggregate demand stimulates aggregate production (Figure 2c). GDP increases, favored by the increase in consumption and investment. Exports increase, associated with the real exchange rate depreciation, is compensated by the increase in imports, associated with the increase in domestic demand

Both patient and impatient households increase consumption (Figure 2d).

Spillovers to the Home country are small. Home banks increase their lending to REA banks through the cross-country interbank market. The additional lending is financed by raising domestic deposits, while lending to domestic firms and households and the bank capital does not greatly change. The Home GDP and CPI inflation essentially stay at their corresponding baseline levels. Given the small impact of the REA LTV shock on the Home economy, the union-wide inflation and real activity do not greatly change. This implies that the monetary policy authority of the monetary union does not greatly increase the monetary policy rate.

4.3 Increase in Home banks lending in the interbank market

Figures 3a-3d show the implications of a permanent increase in the amount of liquidity supplied by the Home banks in the (cross-country) interbank market. This is implemented by assuming an increase of one percentage point in the long-run target of Home banks interbank lending (see eq 4).

Figure 3a reports Home banks increase their lending to REA banks to match the higher target. The interest rate is broadly constant. Home banks shift resources away from loans to domestic households and firms and, at the same time, increase demand for domestic deposits and increase capital. To the opposite, REA banks increase their supply of domestic loans, inducing a fall in the interest rate on loans. REA banks decrease deposits and bank capital, because they rely more on the interbank debt as a source of financing.

Figure 3b shows the effects on borrowing and real estate. They are asymmetric across countries. Given the higher amount of loans to households and entrepreneurs, borrowing, demand for real estate demand increase in the Home country, inducing an increase in the REA real estate prices. The opposite happens in the Home country.

Similarly, cross-country asymmetric dynamics characterize the Home and REA regions (see Figures 3c-3d). The increase in Home loans favour Home aggregate demand, inducing an increase in Home inflation and labor. To the opposite, the same variables decrease in the REA.

Overall, the shock has asymmetric macroeconomic effects on the two regions.

4.4 Increase in the bank capital requirement

Figures 4a-4d report the responses to a permanent increase in the capital requirement simultaneously implemented in both EA regions. The capital requirement Υ_K (see equation **??**) is exogenously increased by 1 percentage point.

Figure 4a reports the responses of the main bank variables. They are broadly symmetric across the two regions. Specifically, banks gradually increase their capital to satisfy the new requirement. To the purpose, they decrease domestic loans supply and, for Home banks, interbank market loans as well. Correspondingly, the interest rates in the domestic and interbank markets for loans increase. Banks also decrease their demand for deposits from domestic patient households, as they can rely on a larger amount of capital. The monetary policy rate is broadly unchanged, because the shock has recessionary macroeconomic effects and the monetary

authority tries to stabilize inflation and economic activity.

As shown in Figure 4b and 4c, the shock induces a reduction in loans to households and entrepreneurs. Their demand for housing decreases, inducing a decrease in real estate prices and an increase in real estate holdings by the patient household. Similarly, aggregate consumption and investment decrease, inducing the reduction in CPI inflation and GDP.

Finally, Figure 4d reports that the drop in aggregate demand can be associated with the reduction in impatient households' and entrepreneurs consumption, that more than compensate the increase in patient households' consumption due to the lower interest rate on deposit. The lower aggregate demand induces a lower demand for labor by firms and, hence, a decrease in the real wage.

Overall, the shock has rather symmetric and recessionary effects across countries. One important caveat applies to our results. As simulations are run under perfect foresight, we are not able to capture possible expansionary effects associated with the reduction in systemic risk, due to the increase in bank capital. The positive effects can, at least partially, compensate the negative effect of lower loans. From this perspective, our results should be seen as an upper bound of the negative effects of the increase in capital requirement on economic activity.

5 Conclusions

The monetary union dimension of the EA, its recent financial crisis and the prolonged recession phase have put new emphasis on financial shocks and the role of banking and financial features for the transmission of monetary policy. This paper has outlined a model, EAGLE-FLI, aimed at analyzing these issues. Its large scale, jointly with its microfoundations, allows to properly analyze them in the EA. Equivalently, EAGLE allows to conduct a quantitative analysis in a theoretically coherent and fully consistent model setup, clearly spelling out all the policy implications. The model can be improved along several dimensions, that can be crucial for further understanding the transmission of spillovers in the EA. For example, the financial structure can be further enriched by allowing for bonds having different maturities. Borrowing constraints can be made occasionally binding. Finally, and related, uncertainty and risk can be added by appropriately changing the solution algorithm. These issues and their policy implications constitute an exciting research agenda.

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Table 1: Households and Firms Behavior

	Home	REA	US	RW
Households				
Discount factor (β)	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$	$1.03^{-\frac{1}{4}}$
Impatient households discount factor (β)	0.96	0.96	0.96	0.96
Entrepreneurs discount factor (β)	0.96	0.96	0.96	0.96
Intertemporal elasticity of substitution (σ^{-1})	1.00	1.00	1.00	1.00
Housing services (ι)	0.80	0.80	0.80	0.80
Inverse of the Frisch elasticity of labor (ζ)	2.00	2.00	2.00	2.00
Habit persistence (κ)	0.70	0.70	0.70	0.70
Share of impatient households (ω^{imp})	0.32	0.30	0.15	0.15
Share of entrepreneurs (ω^{entr})	0.10	0.10	0.10	0.10
Depreciation rate (δ)	0.025	0.025	0.025	0.025
Intermediate-good firms (trad. and nontrad. sectors)				
Substitution btw. labor and capital	1.00	1.00	1.00	1.00
Bias towards capital (α)	0.30	0.30	0.30	0.30
Substitution btw. I-type and J-type labor (η)	4.33	4.33	4.33	4.33
Final consumption-good firms				
Substitution btw. domestic and imported trad. goods (μ_{TC})	2.50	2.50	2.50	2.50
Bias towards domestic tradables goods (v_{TC})	0.31	0.21	0.65	0.58
Substitution btw. tradables and nontradables (μ_C)	0.50	0.50	0.50	0.50
Bias towards tradable goods (v_C)	0.45	0.45	0.35	0.35
Final investment-good firms				
Substitution btw. domestic and imported trad. goods (μ_{TI})	2.50	2.50	2.50	2.50
Bias towards domestic tradables goods (v_{TI})	0.42	0.75	0.70	0.54
Substitution btw. tradables and nontradables (μ_I)	0.50	0.50	0.50	0.50
Bias towards tradable goods (v_I)	0.75	0.75	0.75	0.75

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

Table 2: Financial and Banks Parameters

	Home	REA	US	RW
Households' loan-to-value ratio (V_J)	0.7	0.7	0.7	0.7
Entrepreneurs loan-to-value ratio (V_E)	0.9	0.9	0.9	0.9
Adjustment costs				
Deposits (γ^{dep})	0.0001	0.0001	0.0001	0.0001
Excess bank capital (γ^{x})	0.001	0.001	0.001	0.001
Interbank (γ^{IB})	0.001	n.a.	n.a	n.a

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

Table 3: Steady-State National Accounts (Ratio to GDP, Percent)

	Home	REA	US	RW
Domestic demand				
Private consumption	60	60	63	64
Consumption of impatient households	xxx	xx	xxx	xxx
Private investment	20	20	20	20
Public consumption	20	20	16	16
Trade				
Imports (total)	28	24	11	15
Imports of consumption goods	18	20	7	9
Imports of investment goods	9	4	4	6
Net foreign assets (ratio to annual GDP)	10	-3.75	-15	10
Production				
Tradables	38	39	37	37
Nontradables	61	61	63	63
Labor	52	52	59	59
Share of World GDP	7	16	30	46

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

Table 4: Steady-State Financial Accounts (Ratio to yearly GDP, Percent)

	Home	REA	US	RW
Loans	93.5	91.7	29.4	29.4
Loans to entrepreneurs	33.1	47.5	15.3	15.3
Loans to households	60.4	44.2	14.1	14.1
Interbank	0.0	0.0	n.a.	n.a.
Deposits	85.0	85.0	27.5	27.5
Excess bank capital	0.0	0.0	0.0	0.0

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

Table 5: Price and Wage Markups (Implied Elasticities of Substitution)

	Tradables (θ_T)	Nontradables (θ_N)	Wages ($\eta_I = \eta_J$)
Home	1.20 (6.0)	1.50 (3.0)	1.30 (4.3)
REA	1.20 (6.0)	1.50 (3.0)	1.30 (4.3)
US	1.20 (6.0)	1.28 (4.6)	1.16 (7.3)
RW	1.20 (6.0)	1.28 (4.6)	1.16 (7.3)

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

Table 6: Real and Nominal Rigidities

	Home	REA	US	RW
Adjustment costs				
Imports of consumption goods (γ_{IM^C})	2.00	2.00	2.00	2.00
Imports of investment goods (γ_{IM^I})	1.00	1.00	1.00	1.00
Capital utilization (γ_{u2})	2000	2000	2000	2000
Investment (γ_I)	6.00	6.00	4.00	4.00
Transaction cost function (γ_{v1})	0.029	0.029	0.029	0.029
(γ_{v2})	0.15	0.15	0.15	0.15
Intermediation cost function (γ_{B^*})	0.01	0.01	...	0.01
Calvo parameters				
Wages - households I and J (ξ_I and ξ_J)	0.75	0.75	0.75	0.75
Prices - domestic tradables (ξ_H) and nontradables (ξ_N)	0.92	0.92	0.75	0.75
Prices - exports (ξ_X)	0.75	0.75	0.75	0.75
Degree of indexation				
Wages - households I and J (χ_I and χ_J)	0.75	0.75	0.75	0.75
Prices - domestic tradables (χ_H) and nontradables (χ_N)	0.50	0.50	0.50	0.50
Prices - exports (χ_X)	0.50	0.50	0.50	0.50

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

Table 7: International Linkages (Parameters of Tradable Bundles)

	Home	REA	US	RW
Consumption-good imports				
Substitution btw. consumption good imports (μ_{IMC})	2.50	2.50	2.50	2.50
Bias towards imported consumption goods from ($v^{H,CO}_{IMC}$)				
Home	-	0.211	0.061	0.155
REA	0.546	-	0.135	0.462
US	0.053	0.021	-	0.383
RW	0.401	0.768	0.804	-
Investment-good imports				
Substitution btw. investment good imports (μ_{IMI})	2.50	2.50	2.50	2.50
Bias towards imported investment goods from ($v^{H,CO}_{IMI}$)				
Home	-	0.697	0.064	0.149
REA	0.546	-	0.112	0.400
US	0.053	0.134	-	0.451
RW	0.401	0.169	0.824	-

Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

Table 8: International Linkages (Trade Matrix, Share of Domestic GDP, Percent)

	Home	REA	US	RW
Consumption-good imports				
Total consumption good imports	18.4	20.1	7.3	8.6
Bias towards imported consumption goods from				
Home	-	3.1	0.3	1.1
REA	8.7	-	0.8	3.5
US	1.2	0.5	-	4.0
RW	8.5	16.6	6.2	-
Investment-good imports				
Total investment good imports	9.3	3.7	4.2	6.3
Bias towards imported investment goods from				
Home	-	2.2	0.2	0.7
REA	4.4	-	0.4	2.2
US	0.6	0.7	-	3.4
RW	4.3	0.8	3.6	-

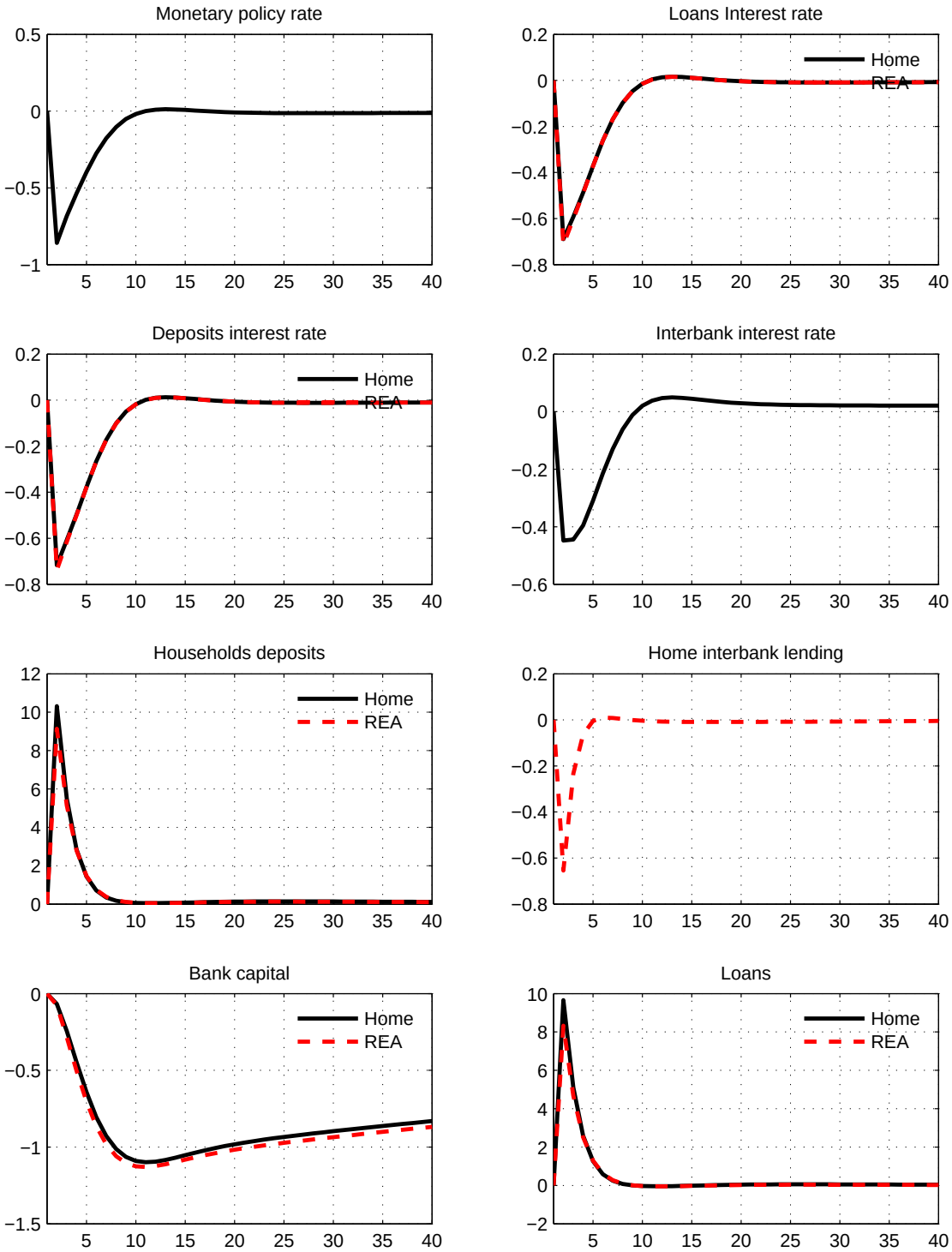
Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

Table 9: Monetary and Fiscal Policy

	Home	REA	US	RW
Monetary authority				
Inflation target ($\overline{\Pi}^4$)	1.02	1.02	1.02	1.02
Interest rate inertia (ϕ_R)	0.87	0.87	0.87	0.87
Interest rate sensitivity to inflation gap (ϕ_Π)	1.70	1.70	1.70	1.70
Interest rate sensitivity to output growth (ϕ_Y)	0.10	0.10	0.10	0.10
Fiscal authority				
Government debt-to-output ratio ($\overline{B_Y}$)	2.40	2.40	2.40	2.40
Sensitivity of lump-sum taxes to debt-to-output ratio (ϕ_{B_Y})	0.10	0.10	0.10	0.10
Consumption tax rate (τ^C)	0.183	0.183	0.077	0.077
Dividend tax rate (τ^D)	0.00	0.00	0.00	0.00
Capital income tax rate (τ^K)	0.19	0.19	0.16	0.16
Labor income tax rate (τ^N)	0.122	0.122	0.154	0.154
Rate of social security contribution by firms (τ^{W_f})	0.219	0.219	0.071	0.071
Rate of social security contribution by households (τ^{W_h})	0.118	0.118	0.071	0.071

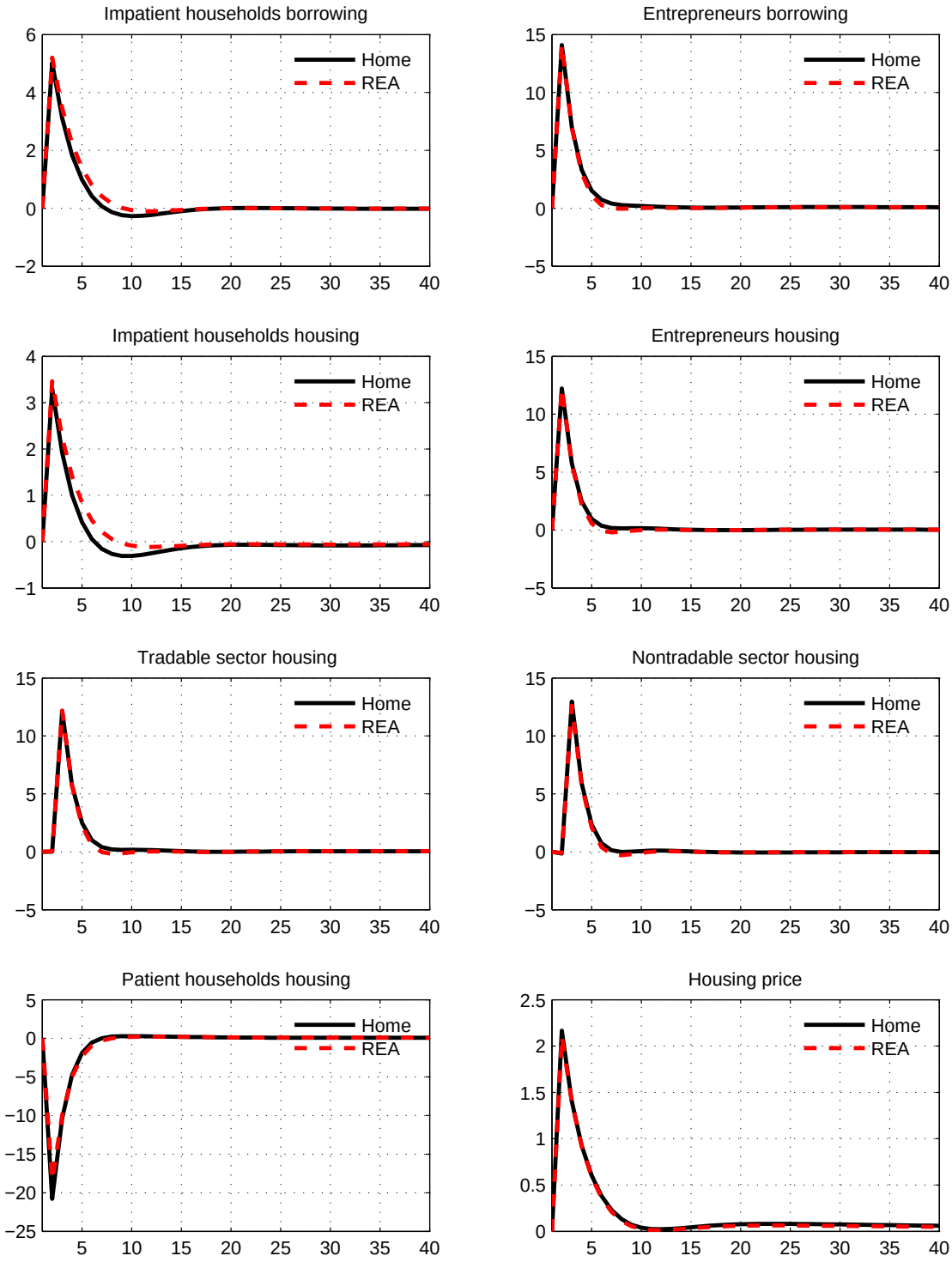
Note: REA=Rest of Euro Area; US=United States; RW=Rest of World

Figure 1a. Reduction in the EA interest rate – Effects on bank variables



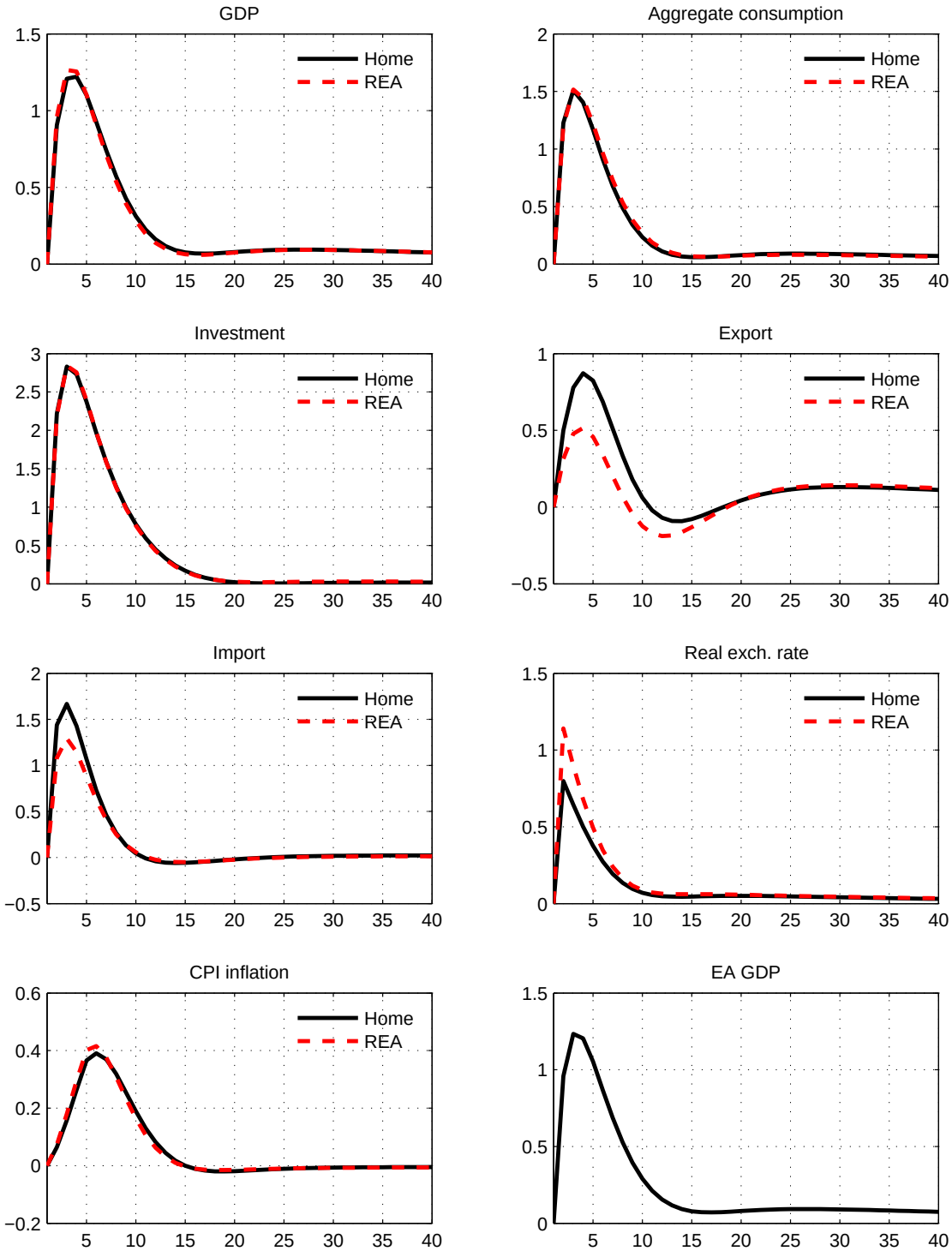
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline, except for interest rates (annualized percentage-point deviations) and the interbank position-to-GDP ratio (percentage-point deviations).

Figure 1b. Reduction in the EA interest rate – Effects on borrowing and housing



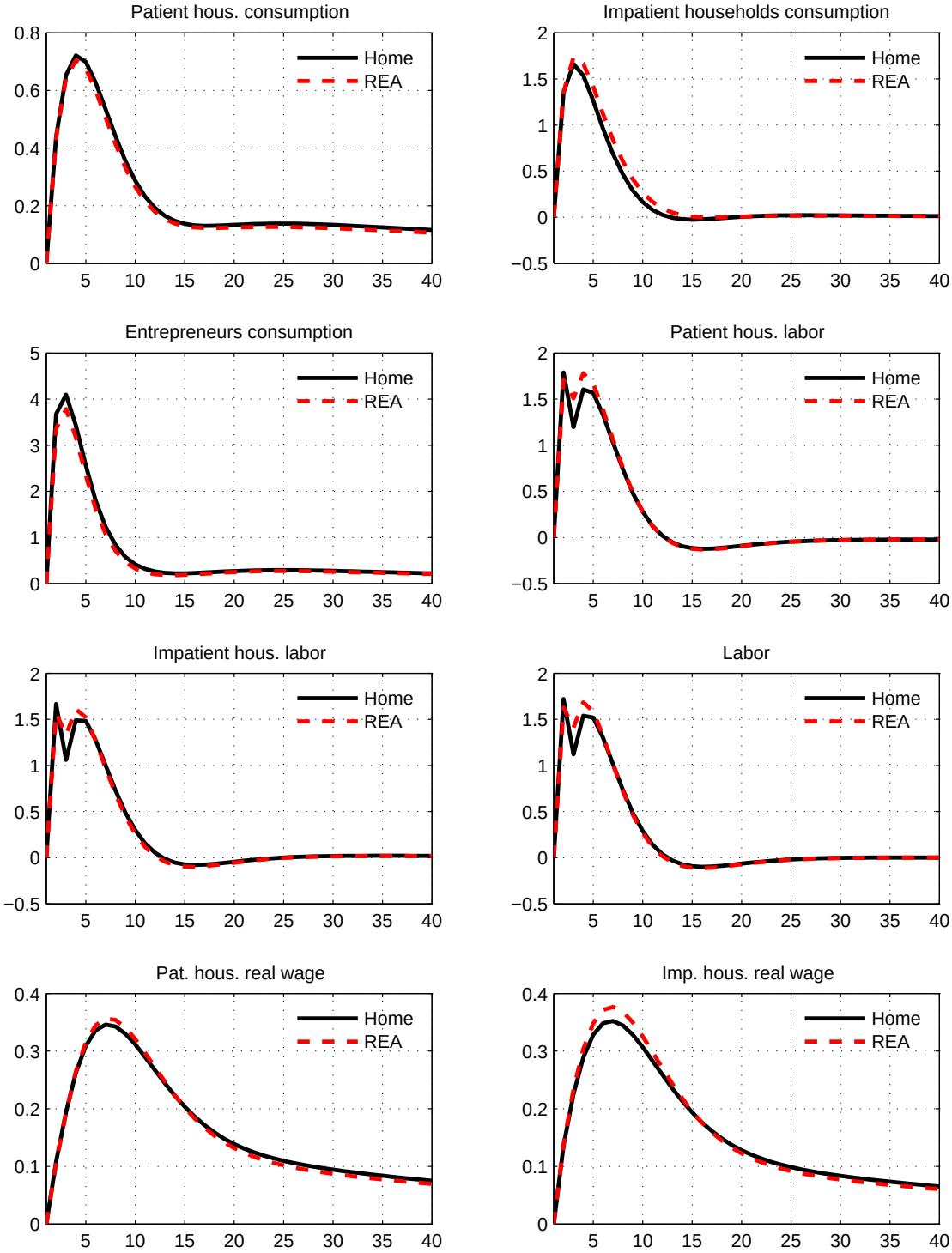
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline.

Figure 1c. Reduction in the EA interest rate – Effects on main macro variables



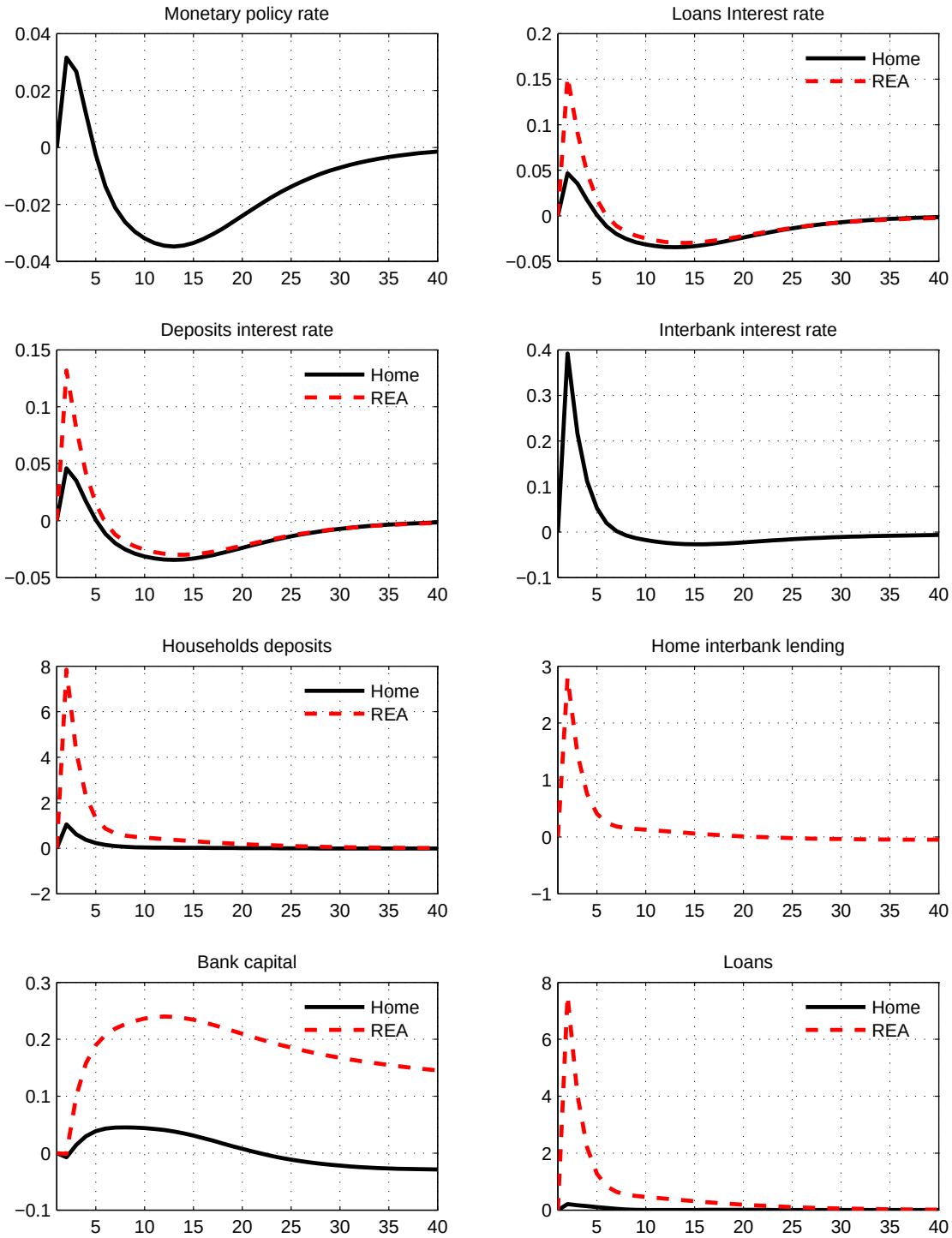
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline, except for inflation (annualized percentage-point deviations). GDP and its components are reported in real terms.

Figure 1d. Reduction in the EA interest rate – Effects on consumption and labor



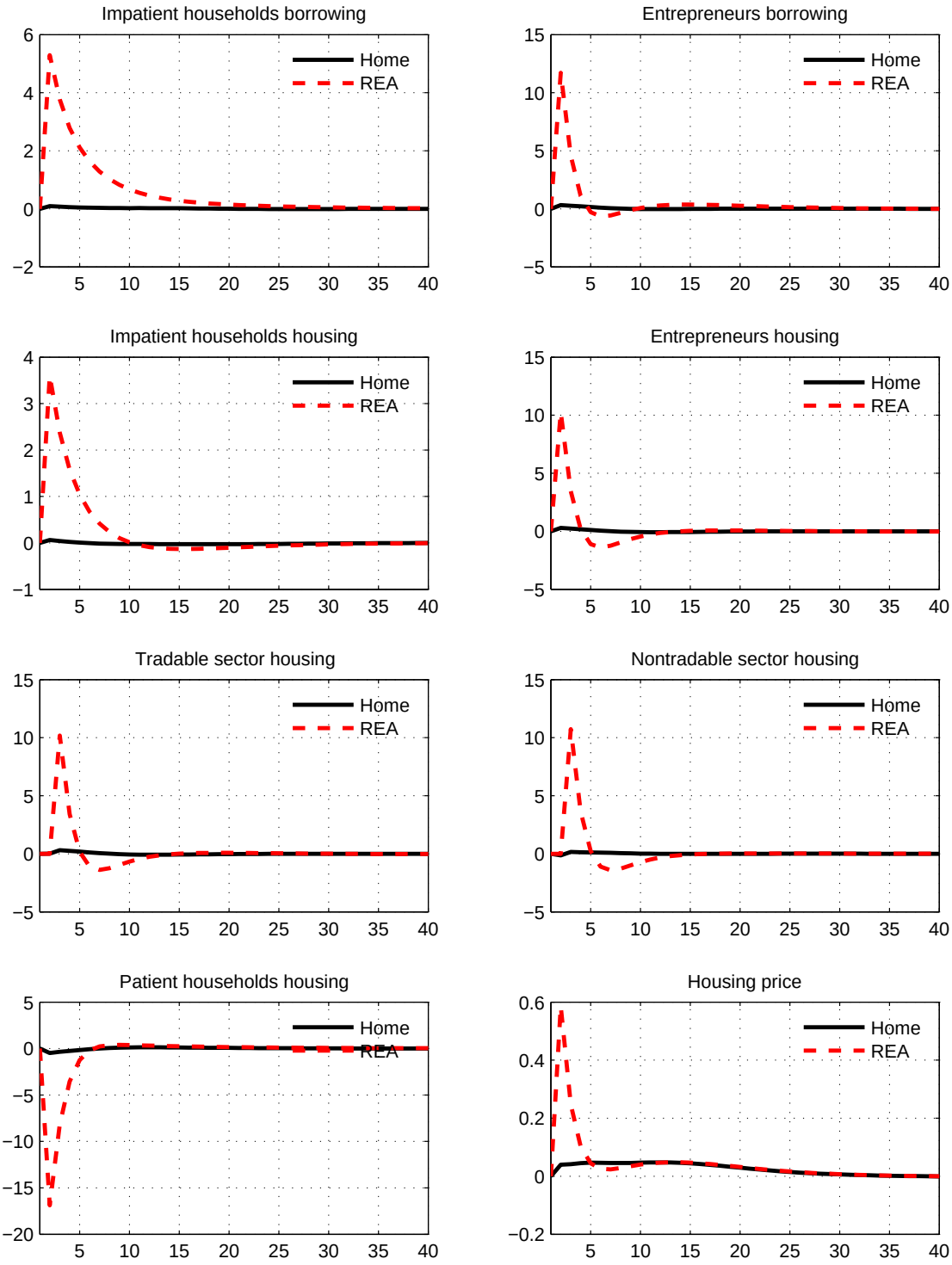
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline.

Figure 2a. Increase in REA loan-to-value ratio – Effects on bank variables



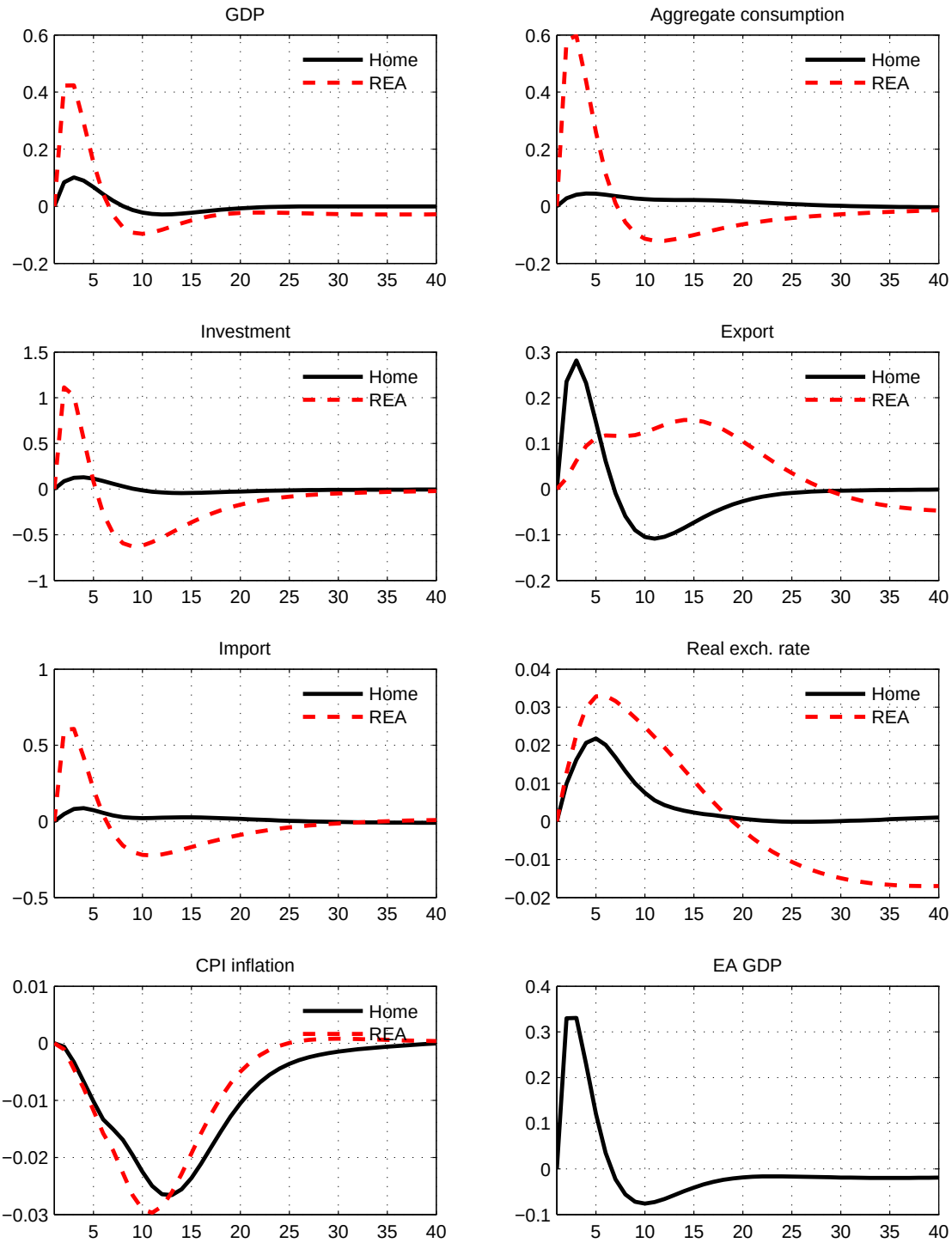
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline, except for interest rates (annualized percentage-point deviations) and the interbank position-to-GDP ratio (percentage-point deviations).

Figure 2b. Increase in REA loan-to-value ratio – Effects on borrowing and housing



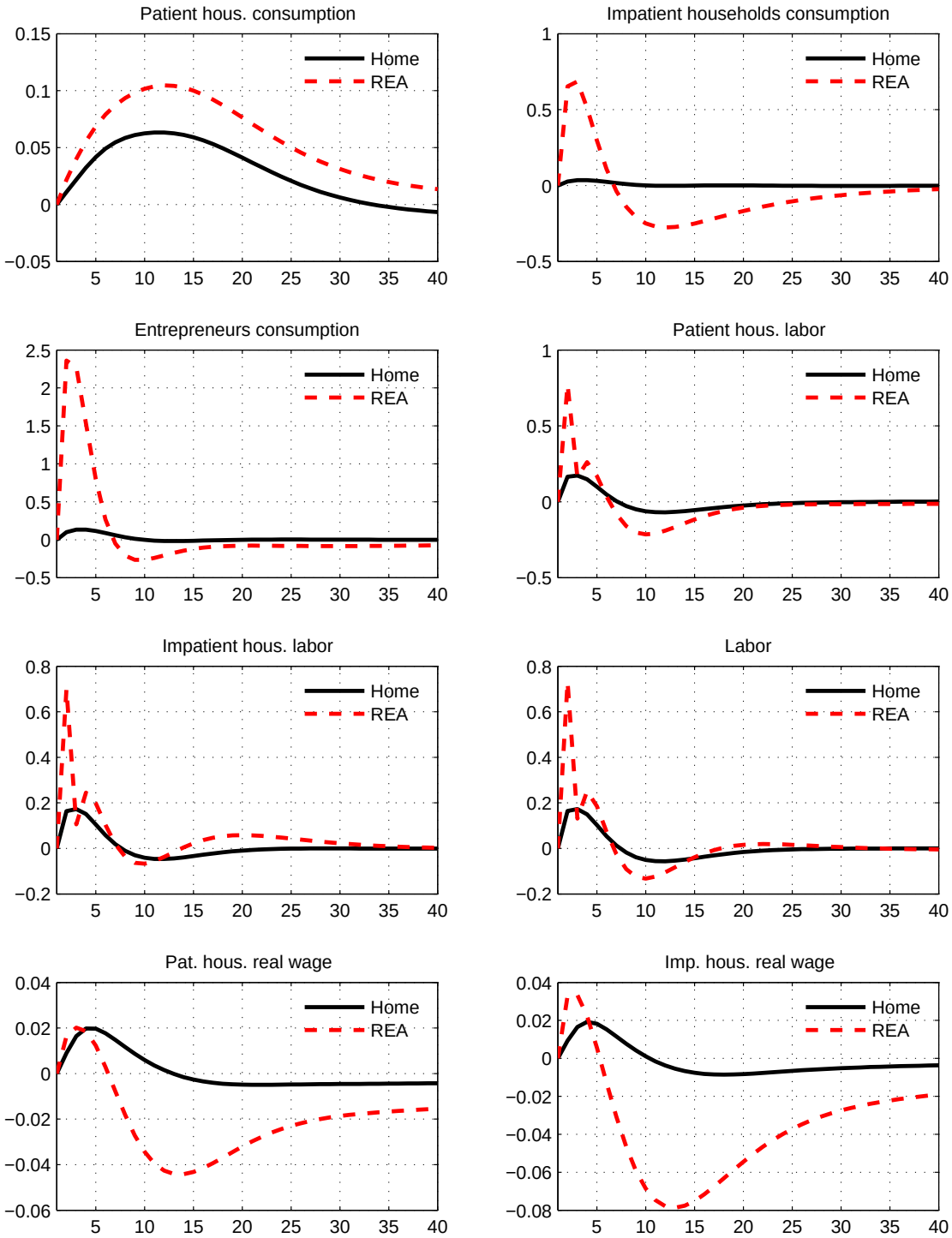
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline.

Figure 2c. Increase in REA loan-to-value ratio – Effects on main macro variables



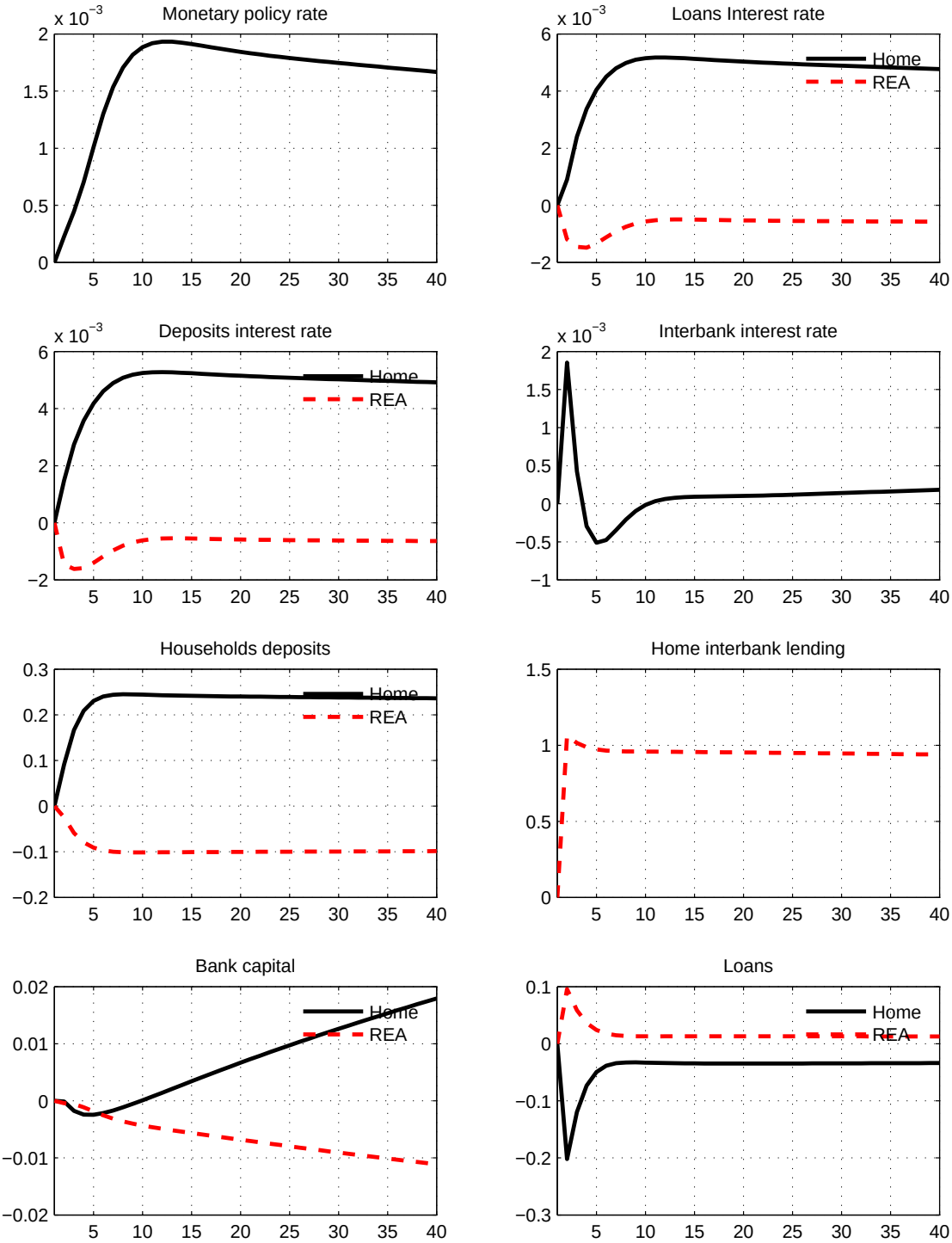
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline, except for inflation (annualized percentage-point deviations). GDP and its components are reported in real terms.

Figure 2d. Increase in REA loan-to-value ratio – Effects on consumption and labor



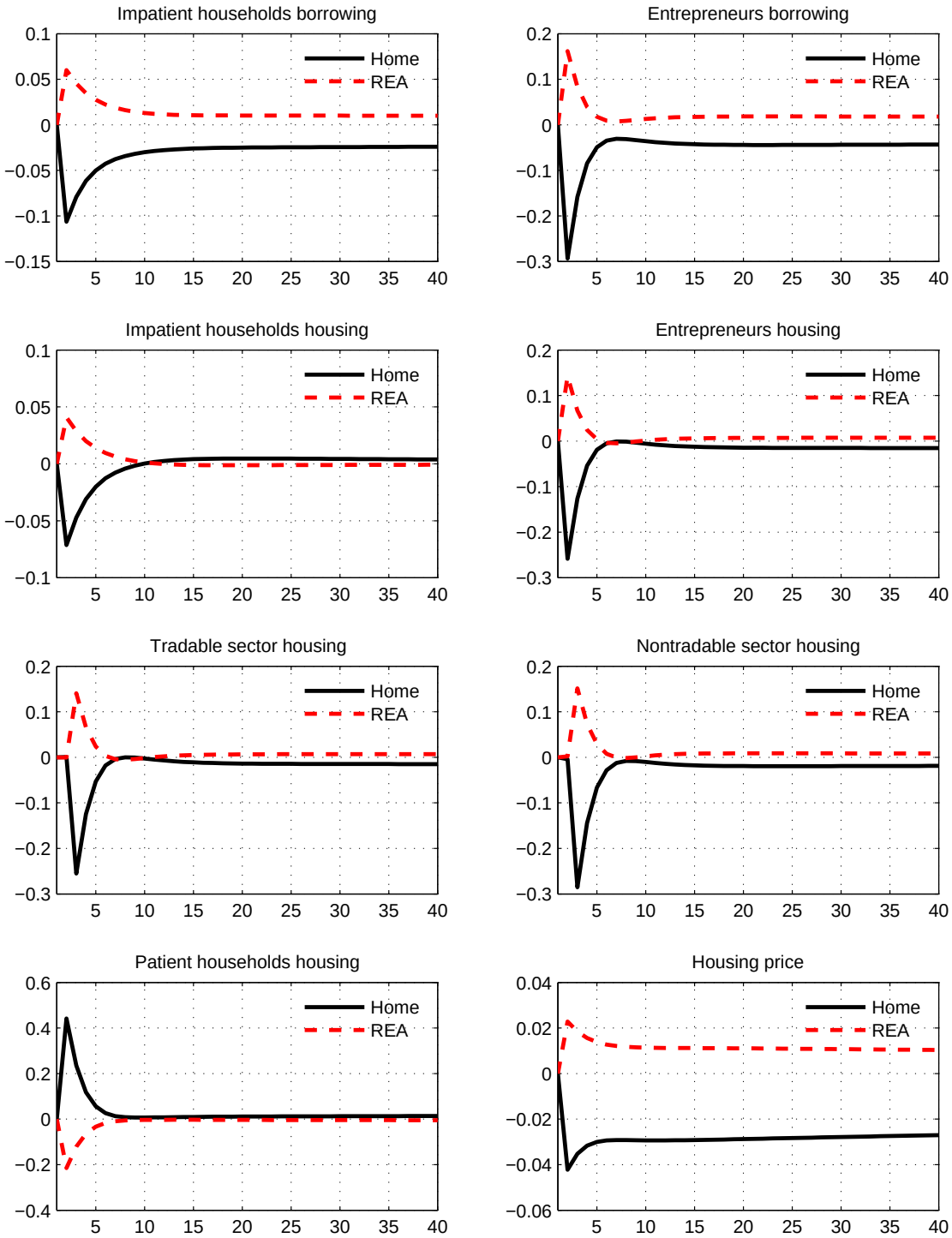
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline.

Figure 3a. Increase in Home long-run interbank position – Effects on bank variables



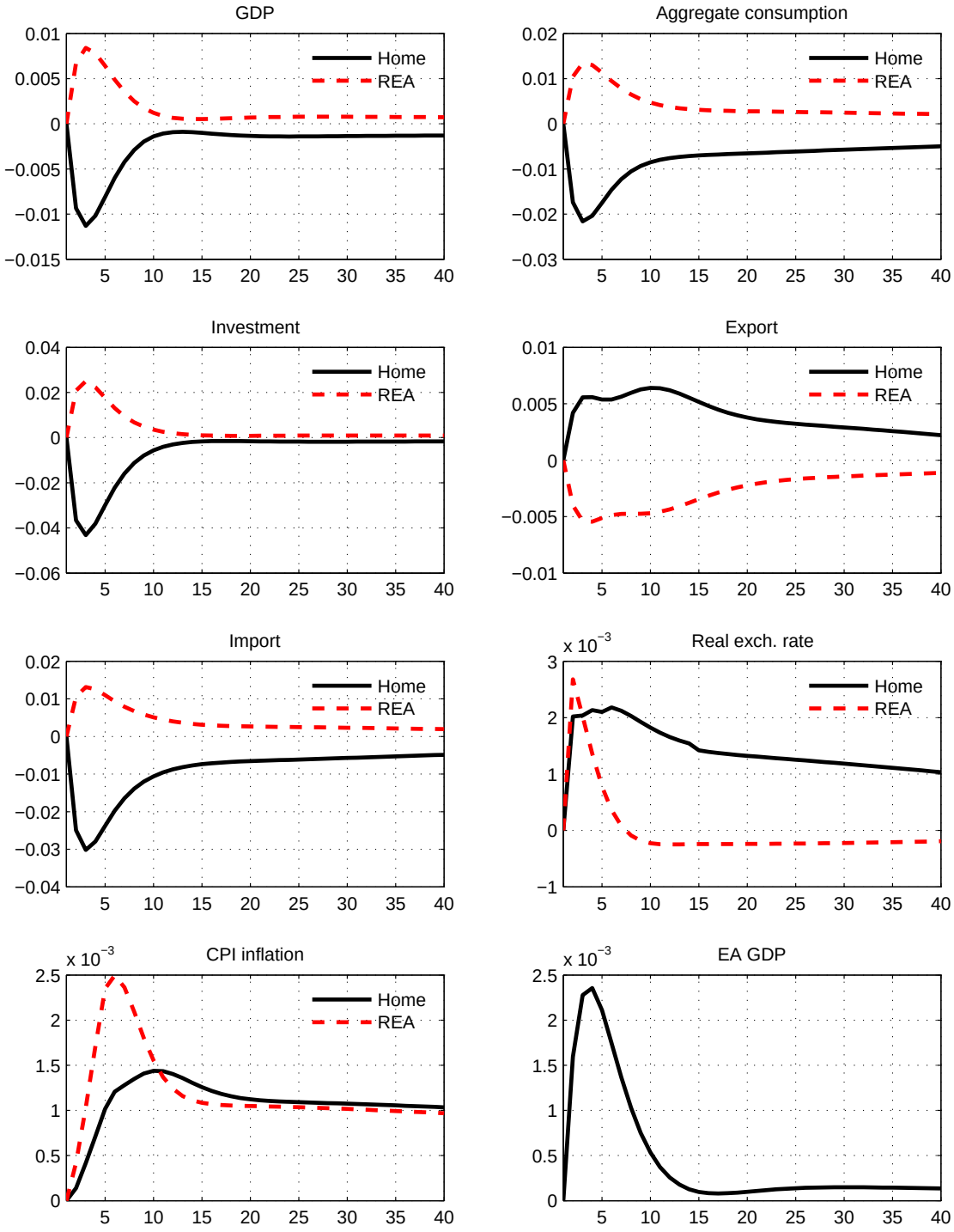
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline, except for interest rates (annualized percentage-point deviations) and the interbank position-to-GDP ratio (percentage-point deviations).

Figure 3b. Increase in Home long-run interbank position – Effects on borrowing and housing



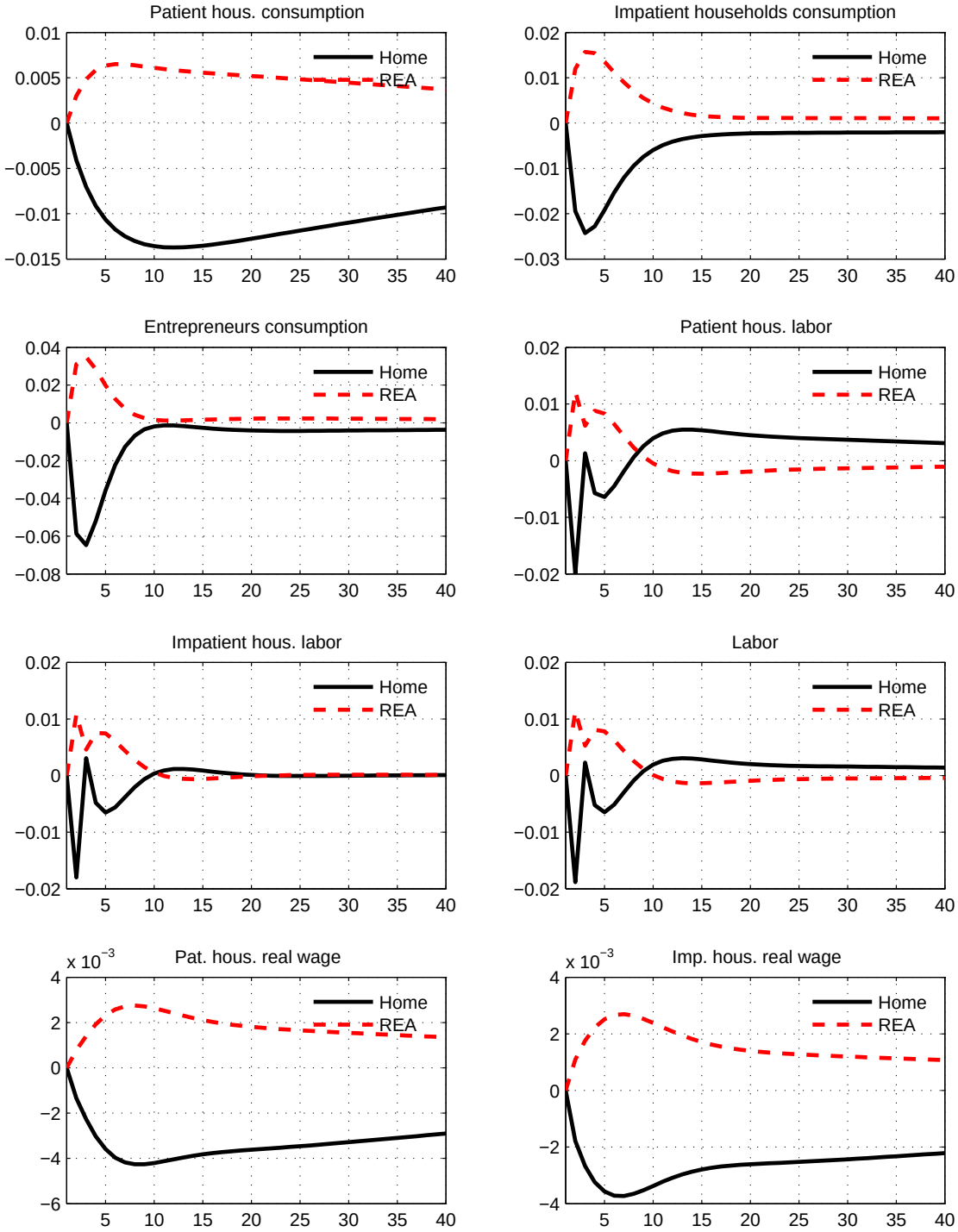
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline.

Figure 3c. Increase in Home long-run interbank position – Effects on main macro variables



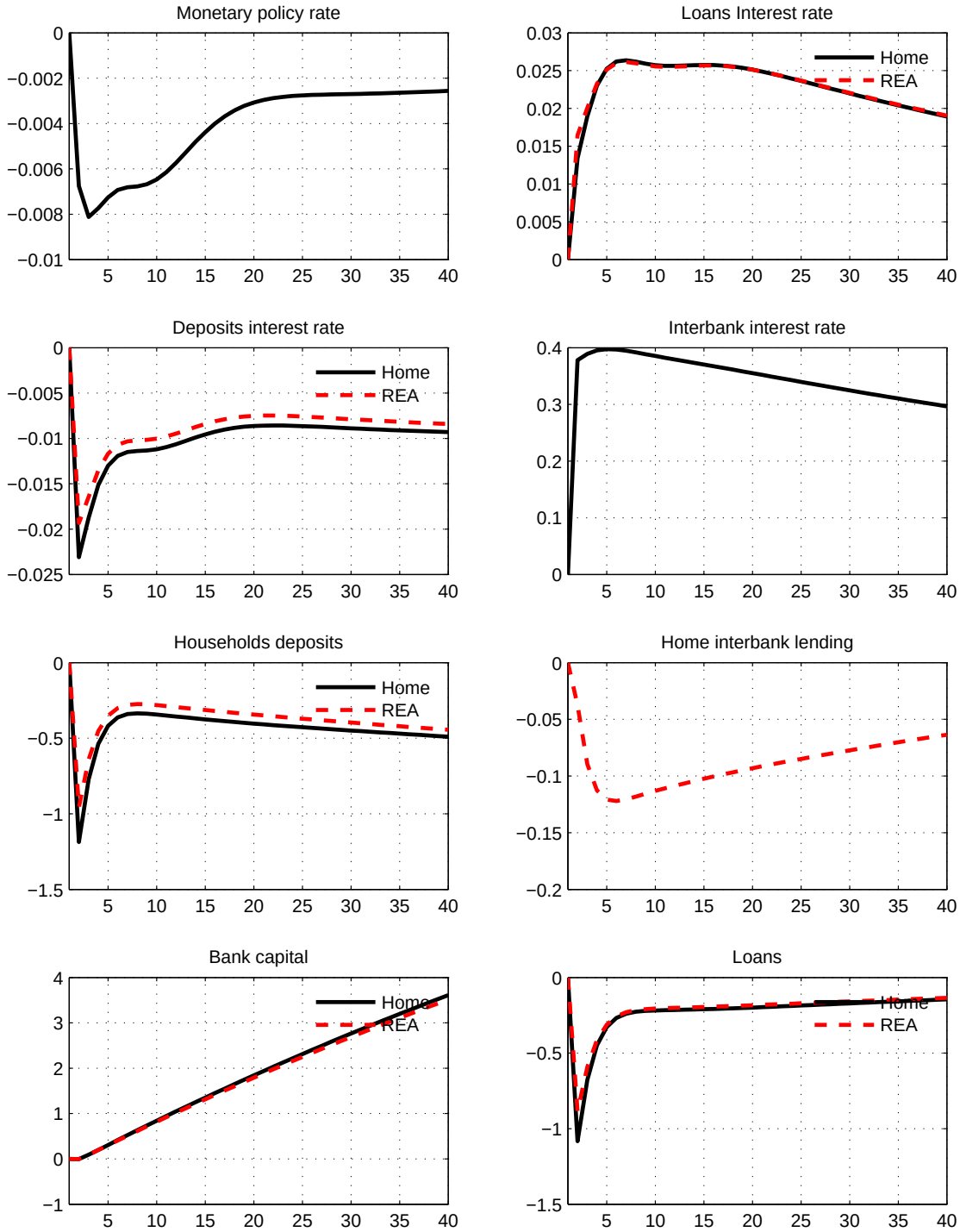
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline, except for inflation (annualized percentage-point deviations). GDP and its components are reported in real terms.

Figure 3d. Increase in Home long-run interbank position – Effects on consumption and labor



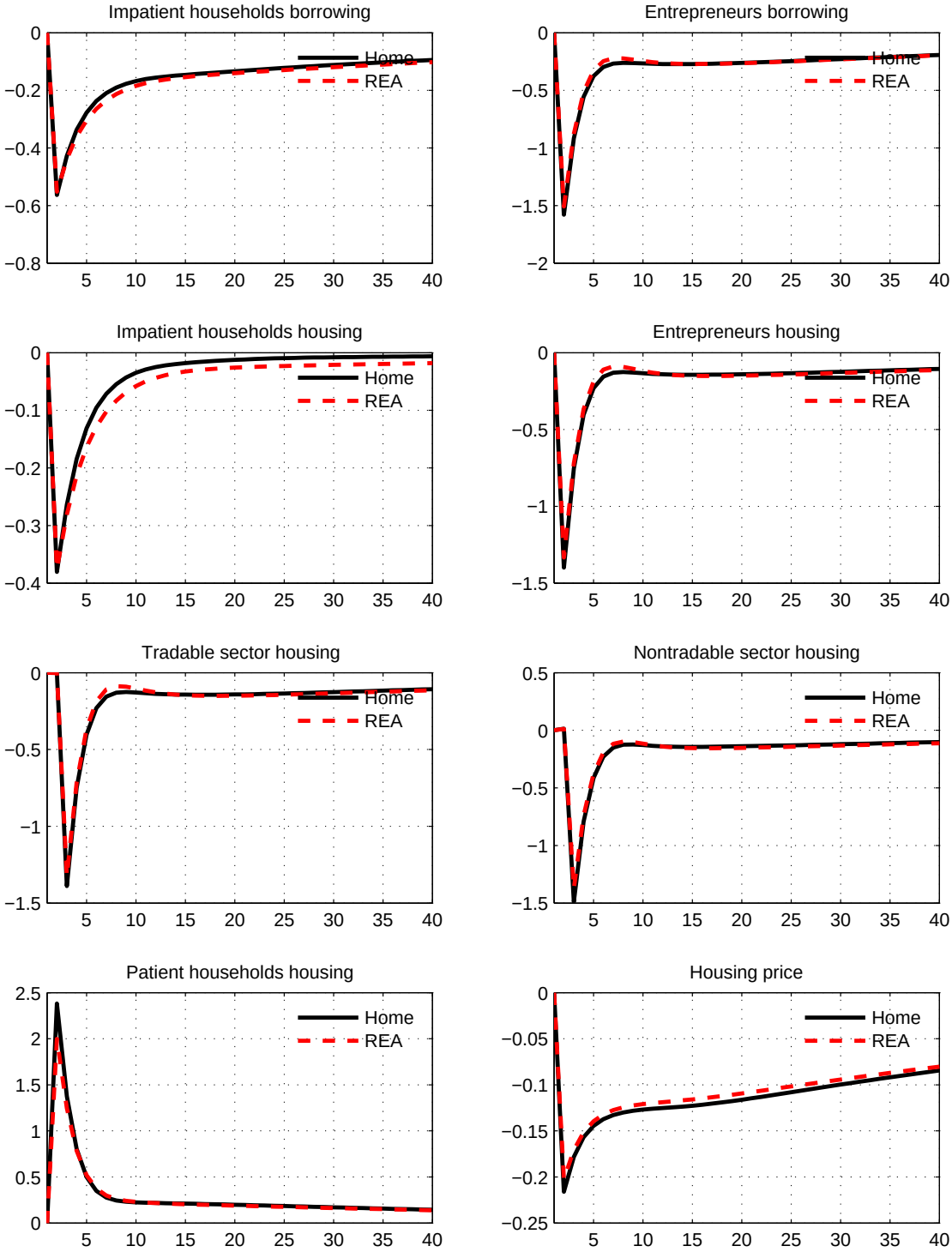
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline.

Figure 4a. Increase in EA bank capital requirement – Effects on bank variables



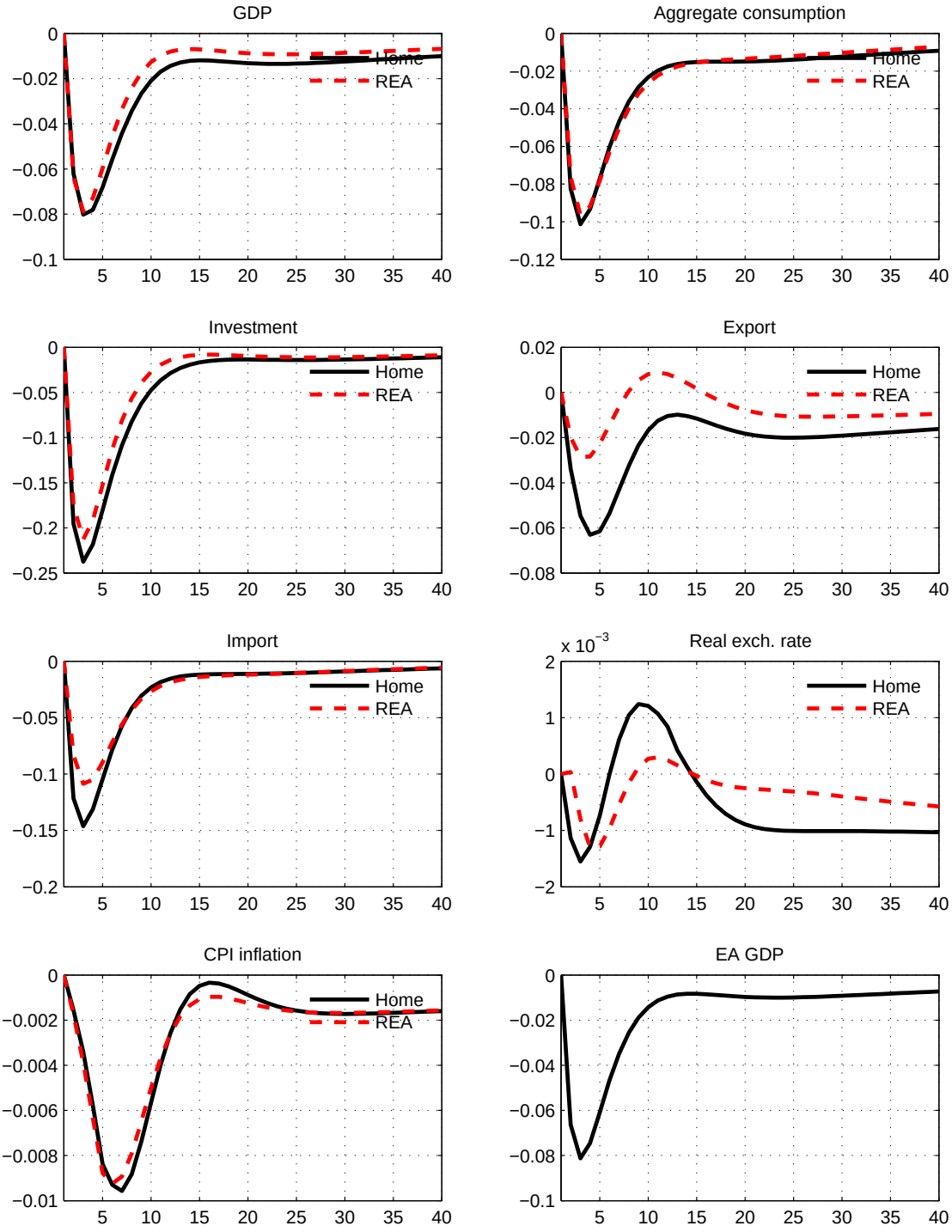
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline, except for interest rates (annualized percentage-point deviations) and the interbank position-to-GDP ratio (percentage-point deviations).

Figure 4b. Increase in EA bank capital requirement – Effects on borrowing and housing



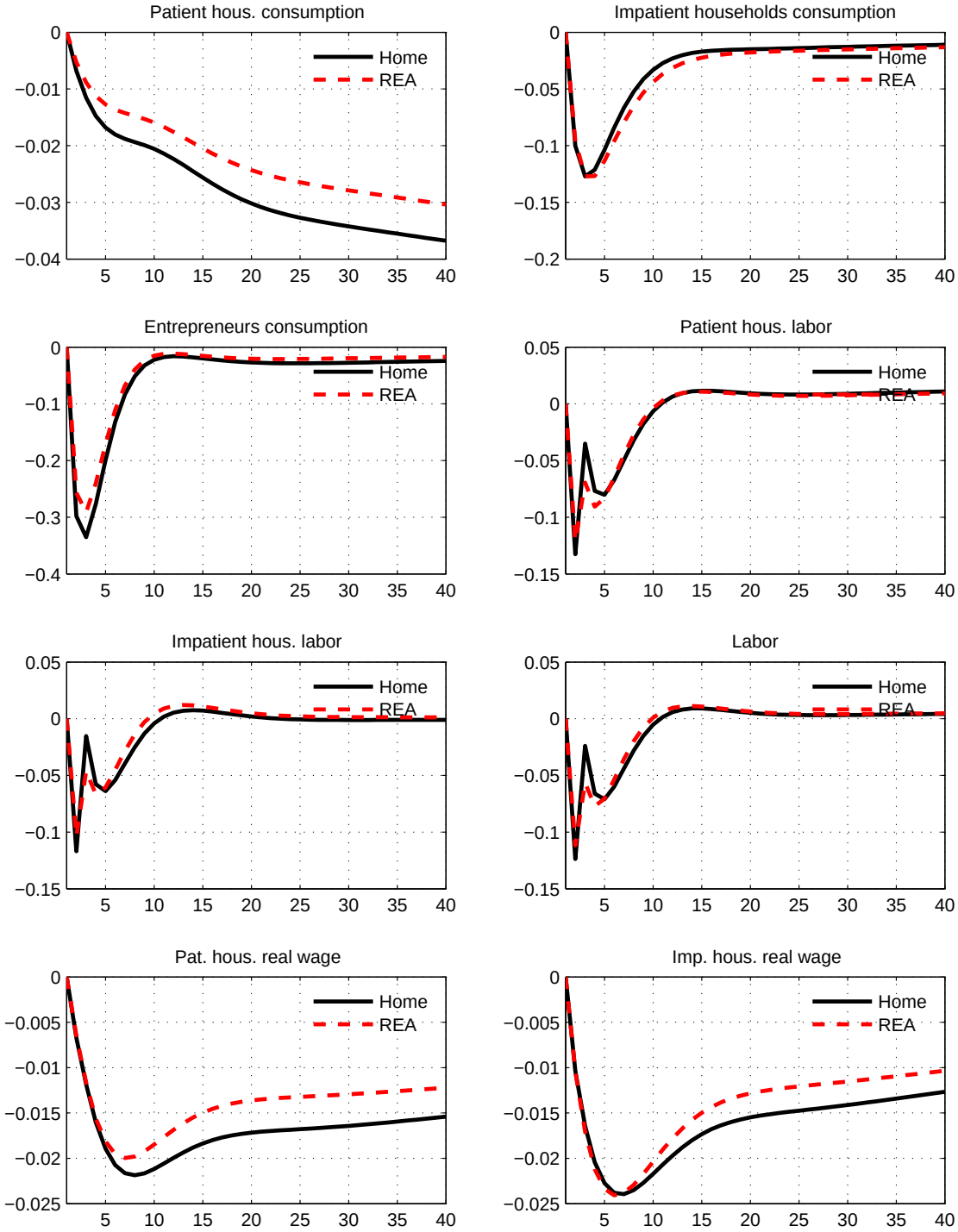
Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline.

Figure 4c. Increase in EA bank capital requirement – Effects on main macro variables



Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline, except for inflation (annualized percentage-point deviations). GDP and its components are reported in real terms.

Figure 4d. Increase in EA bank capital requirement – Effects on consumption and labor



Horizontal axis: quarters. Vertical axis: percentage deviations from the baseline.