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The global savings glut and the housing boom☆

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ABSTRACT

The U.S. housing boom from 2000 to 2006 consisted of two fundamentally different phases. An increase in foreign credit supply (a savings glut) can explain the initial *countercyclical* run-up in house prices from 2000 through 2002, whereas an increase in domestic credit demand –driven by a relaxation of domestic credit standards– can explain the subsequent *procyclical* boom phase from 2003 to 2006. A tightening of domestic credit standards can fully explain the bust from 2007 to 2010. I base these conclusions on a quantitative open economy model with housing and collateralized foreign debt. Countercyclical government spending financed by a lump sum tax stabilizes house prices, output and domestic inflation over the entire boom period, pushes the economy away from the zero lower bound, and raises domestic utility.

1. Introduction

In the first half of the 2000′s, the US economy experienced a massive boom in house prices, and, subsequently, a collapse that initiated one of the worst economic downturns in the history of the industrialized world. Despite an extensive literature on the topic, economists have not yet reached a consensus on the underlying sources of the boom. In this paper, I argue that the run-up in house prices between 2000 and 2006 cannot plausibly be attributed to a single factor. Notably, as illustrated in Fig. 1, the boom consisted of two fundamentally different phases:

PHASE 1: An initial *countercyclical* run-up in house prices from 2000 through 2002 where the real interest, output and inflation all declined, and the real exchange rate appreciated, and, subsequently,

PHASE 2: A *procyclical* boom from around 2003 to 2006 where all of these patterns were reversed, i.e. the real interest rate, output and inflation all increased and the real exchange rate depreciated.

These patterns suggest that house prices could *not* have been driven by the same underlying factor(s) before and after 2003.

Using an open economy model with borrowing constraints, I show that a Global Savings Glut, as proposed by Bernanke (2005; 2007; 2010), can explain the initial *countercyclical* run-up in house prices shown in Figure 1. According to Bernanke (2005; 2007; 2010), increased capital inflows to the United States from countries in which desired savings ex-

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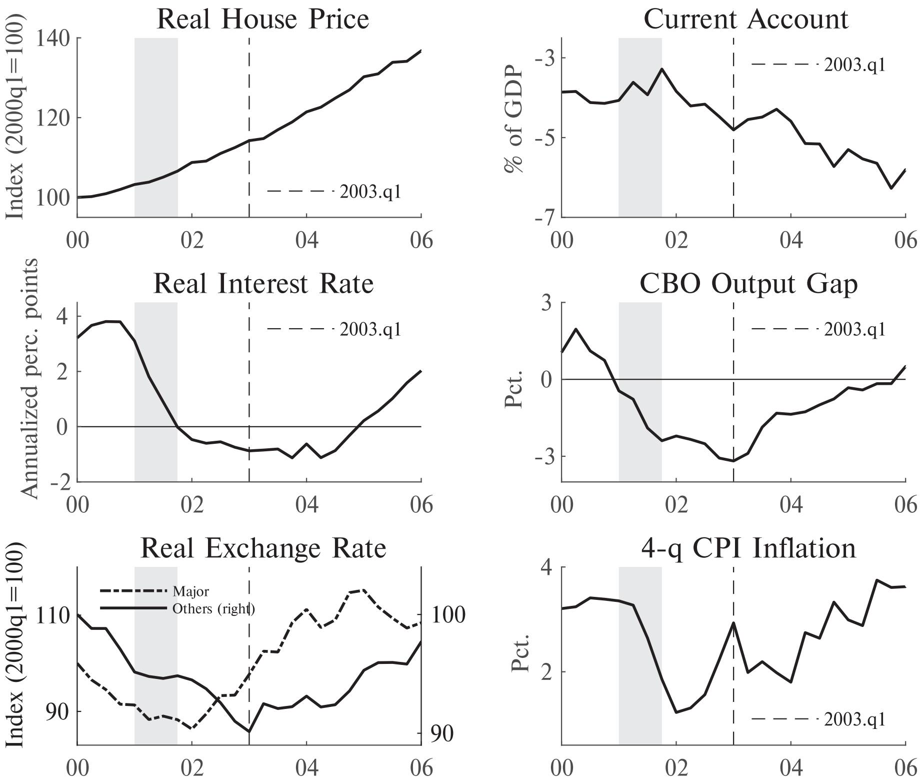

Fig. 1. Key macroeconomic variables 2000–2006. Notes: Real house prices are measured by the All-transactions house price index of the Federal Housing Finance Agency deflated by the Consumer Price Index. The real interest rate is measured by the effective Federal Funds Rate subtracted by the 1-year ahead CPI inflation forecast from the Survey of Professional Forecasters. The real exchange rate measures are the real trade weighted U.S. Dollar indices for major currencies ("major") and other important trading partners ("others"), respectively. Shaded areas indicate U.S. recessions. Sources: Board of Governors of the Federal Reserve, Bureau of Economic Analysis, Bureau of Labor Statistics, Congressional Budget Office, Federal Housing Finance Agency. All data is taken from the Federal Reserve Economic Data (FRED) database.

ceeded desired investment (most notably China) brought down U.S. mortgage-related interest rates and contributed to the run-up in house prices. A large strand of microeconometric evidence shows that the securitization process led to a substantial rise in credit supply in the U.S. mortgage market (Mian and Sufi, 2009; 2011). Caballero and Krishnamurthy (2009) and Bernanke et al. (2011) link the securitization process to foreign capital flows which were channeled into the U.S. mortgage market through the purchase of mortgage-backed securities.

Along these lines, I demonstrate that a savings glut, modelled as a shock to the discount factor of foreign lenders, can account for *all* of the observed patterns in Fig. 1 from 2000 through 2002, namely the increase in house prices, the decline in the real interest rate, the real exchange rate appreciation, the current account deterioration, and the declines in both output and inflation. Specifically, an increase in foreign savings generates a capital inflow that lowers domestic interest rates and increases house prices. But at the same time, the reduction in foreign demand and the real dollar appreciation associated with the savings glut shock induce a trade deficit and a decline in domestic production. Therefore, the savings glut pushes the output gap persistently into negative territory in my model as observed in the data in Fig. 1.[1]

What explains the subsequent procyclical boom phase from 2003 to 2006? A vast empirical literature has documented that collateral requirements for marginal borrowers were relaxed during the housing boom (Demyanyk and Hemert, 2011; Duca et al., 2011; Favilukis et al., 2013; Geanakoplos, 2010).[2] Along these lines, I demonstrate that a relaxation of domestic borrowing constraints in my model can explain all of the observed patterns in the data in Fig. 1 over the 2003–2006 period. Specifically, a domestic credit liberalization generates an increase in domestic demand for foreign credit, putting an upward pressure on interest rates as observed in Fig. 1. Moreover, when domestic households are allowed to borrow more, they increase their spending of both non-durable goods and housing, leading to an increase in domestic production, inflation and house prices, as well as a rising current account deficit and a real exchange rate depreciation.

[1] The currencies of most "savings glut" countries, such as China and other Asian emerging market economies and oil producers like Saudi Arabia, are included in the "other important trading partners" exchange rate index shown in Figure 1.

[2] Notably, Justinano et. al. (2021) find that the private-label securization boom started in the summer of 2003, marking a turning point in the dynamics of the housing boom.

Finally, turning to the housing market bust from 2007 to 2010, this was associated with a large contraction in LTV ratios as well as a sharp rise in mortgage default rates in the data (e.g., Duca et al., 2011; Mian and Sufi, 2009). Accordingly, in my model, a tightening of domestic borrowing constraints, coupled with a binding zero lower bound on the nominal interest rate, can fully explain the house price bust, including the sharp declines in output and interest rates and the rapid current account improvement observed in the data.

Could policymakers have prevented the housing boom? Specifically, can policymakers stabilize asset prices without violating the Fed's dual mandate of maintaining price stability and maximum employment? This has arguably been one of the most important policy questions of the past two decades (Adam and Woodford, 2021; Basel Committee on the Global Financial System, 2010; Bernanke and Gertler, 2001; Collard et al., 2017; IMF, 2011; Rudebusch, 2005). To the best of my knowledge, my paper is the first to show that a savings glut shock gives rise to countercyclical house price dynamics. This finding has crucial implications for policy. First, as I demonstrate, a countercyclical Loan-to-Value (LTV)-ratio (as proposed by, e.g., Basel Committee on the Global Financial System, 2010 and IMF, 2011), implies that credit restrictions should be *relaxed* in response to the savings glut shock. In the model, this serves to amplify the boom in house prices, counteracting the purpose of macroprudential regulation. Second, a positive response to house price appreciation in the central bank's policy rule helps stabilize house prices but it amplifies the declines in both inflation and output stemming from the savings glut. Thus, neither monetary nor macroprudential responses appear desirable when the economy is subject to a savings glut.[3] In contrast, I show that countercyclical government spending financed by a lump-sum tax can simultaneously stabilize house prices, output and domestic inflation over the entire boom period and help the economy avoid a zero lower bound episode. Intuitively, countercyclical government spending (on domestically produced goods) increases domestic output and inflation, thus pushing up interest rates. Higher interest rates (and taxes) serve to stabilize domestic house prices. On the other hand, government spending induces a large exchange rate appreciation which raises the real wage, leading to an equilibrium rise in non-durable consumption and utility.

These findings have implications that go beyond the boom-bust cycle of the 2000's. Notably, the Global Savings Glut Hypothesis (Bernanke, 2005; 2007; 2010) offers a coherent explanation to several macroeconomic developments in advanced economies in recent decades, including the secular downward drift in interest rates (Del Negro et al., 2017; Holston et al., 2017), the slowdown in GDP growth (Summers, 2014), the increase in asset price volatility (Adam et al., 2021), the sustained current account deficit of the U.S. as well as the persistently low rates of inflation following the Great Recession (Constancio, 2016; Jørgensen and Lansing, 2022). In my model, the effects of a savings glut are consistent with *all* of the abovementioned developments. My results suggest that countercyclical government spending may provide a feasible policy response to a savings glut as it can simultaneously stabilize asset prices, output and inflation and push the economy away from the zero lower bound, thus adressing several of the most important policy questions since the turn of the century.

Related literature

My paper is related to the literature investigating the fundamental driving forces of the housing boom and bust. This literature can –broadly speaking– be divided into three strands, emphasizing the role of collateral requirements (Favilukis et al., 2017; Ferrero, 2015; Garriga et al., 2019), credit supply (Justiniano et al., 2014; 2019) and expectations (Adam et al., 2011; Boz and Mendoza, 2014; Case and Shiller, 2003; Case et al., 2012; Glaeser and Nathanson, 2015; 2017; Kaplan et al., 2020; Piazzesi and Schneider, 2009; Shiller, 2007).[4]

Several papers have investigated the role of looser collateral requirements in driving house prices. Justiniano et al. (2015) show that a relaxation of borrowing constraints has virtually no effects on house prices in a closed economy model because the responses of domestic borrowers and lenders wash out in the aggregate. In contrast, in an open economy model, Ferrero (2015) demonstrates that a credit liberalization can have large effects on domestic house prices as it generates a capital inflow from abroad. A common feature of closed and open economy models, however, is that a relaxation of borrowing constraints increases the *demand* for credit, putting an upward pressure on the real interest rate, which does not happen in the data in the early 2000′s.[5]

Other papers have considered the effects of lower interest rates on house prices in small open economy models with borrowing constraints (e.g., Adam et al., 2011; Garriga et al., 2019; Kiyotaki et al., 2011). These papers, however, treat the real interest rate as an exogenous variable. As the data in Fig. 1 shows, interest rates and house prices displayed negative co-movement in the early 2000′s but *positive* co-movement from around 2003 onward, increasing in tandem.[6] Gaining a more complete understanding of what drove the boom-bust cycle therefore requires a framework in which the real interest rate is endogenously determined through the interaction between credit demand and supply.[7]

[3] Providing a formal analysis of optimal monetary, macroprudential or fiscal policy exceeds the scope of my paper.

[4] Several of these papers emphasize the role of *both* credit conditions and expectations.

[5] This point has been prominently voiced by Justiniano et al. (2019).

[6] Justiniano et al. (2021) find evidence of a drop in the *spread* between mortgage and Treasury rates in 2003 (dubbed the “mortgage rate conundrum”). Notwithstanding, real mortgage rates as measured by the 30-year fixed mortgage rate subtracted by the 10-year ahead CPI inflation forecast from the Survey of Professional Forecasters *rose* from 3.0 percent in 2003.q2 to 4.1 percent in 2006.q2, implying an increase in aggregate U.S. credit demand.

[7] Kaplan et al. (2020) make a similar point. These authors argue that credit conditions is not a plausible driver of house prices because, in the presence of rental markets and long-term debt contracts, few consumers face binding credit constraints. The authors, however, abstract from movements in the risk free real interest rate.

In this sense, my paper is closely related to Justiniano et al. (2014, 2019). As these authors point out, a simultaneous rise in mortgage debt and drop in interest rates implies an expansion in the *supply* of credit. Similarly to these papers, I find that a progressive increase in credit supply caused interest rates to drop and house prices to rise in the early 2000′s. However, I find that changes in U.S. credit *demand* –driven by movements in collateral requirements– are crucial in explaining the data from around 2003 onward. Moreover, while Justiniano et al. (2014, 2019) treat credit supply as an exogenous variable, I explicitly model the shocks that drove the inflow of foreign capital in a medium-scale two-country model.[8] First, this allows me to analyze the broader macroeconomic implications of a savings glut shock. Particularly, my paper shows that a savings glut gives rise to countercyclical house price dynamics. Second, it enables me to conduct counterfactual policy experiments. As I demonstrate, countercyclical government spending in the domestic country can help remedy many of the adverse effects of a savings glut shock.

My paper is related to the extensive literature on global imbalances (Caballero et al., 2008a; Mendoza et al., 2009). Much attention has been devoted to explaining the strong negative correlation between house prices and the current account observed in the U.S. and many other countries in the 2000's (Adam et al., 2011; Caballero et al., 2008b; Favilukis et al., 2017; Ferrero, 2015; Justiniano et al., 2014). My results suggest that U.S. current account dynamics were primarily driven by a savings glut in the early 2000′s but by changes in domestic credit restrictions from around 2003 onward.

Finally, several papers have emphasized the role of expectations as a driver of house prices (e.g., Adam et al., 2011; Gelain et al., 2018; Glaeser and Nathanson, 2017; Kaplan et al., 2020). My results are not inconsistent with the expectations hypothesis. The core contribution of my paper, however, is to identify the structural shocks that can account for the observed movements in house prices, interest rates, and other key variables in the data over the boom-bust cycle.[9]

The remainder of the paper is organized as follows. Section 2 presents an open economy model with housing and collateralized foreign debt. Section 3 contains the calibration of the model. In Section 4, I identify the structural shocks that can account for the observed movements in house prices and other key macroeconomic variables during the boom period from 2000 to 2006. Section 5 analyzes the fundamental drivers of the housing market bust from 2007 to 2010. Section 6 contains counterfactual policy experiments. Finally, Section 7 concludes.

2. A Two-Country Model with borrowing constraints

This section presents an open economy model with housing and collateralized foreign debt which builds on Ferrero (2015).

Two countries of equal size form the world economy. In each country, a representative household consists of a continuum of measure one of workers. Households consume a composite of goods produced domestically and abroad as well as housing. Housing is assumed to be fixed. Following Ferrero (2015), I assume that domestic consumers are relatively less patient than foreign consumers ($\beta < \beta^*$), thus facing a binding collateral constraint in the vicinity of the steady state.[10] Final goods producers package differentiated intermediate goods inputs under perfect competition, while intermediate goods producers are monopolistically competitive. The only production input in the intermediate goods sector is labor, which is an aggregate of intermediate labor inputs provided by a representative labor agency. Both prices and wages are set on a staggered basis. The law of one price holds, but home bias in consumption means that purchasing power parity is violated. The two countries can trade a one-period nominal risk free bond.

I extend Ferrero's (2015) model along three dimensions. First, I introduce a fiscal policy authority in each country. Second, I introduce a zero lower bound restriction on the nominal interest rate in each country.[11] Third, I introduce a shock to the discount factor of foreign consumers, aimed to capture the effects of a savings glut. The other shock in the model is a shock to the Loan-to-Value (LTV) ratio faced by domestic consumers which represents changes in domestic credit standards.

Domestic consumers

The representative household gains utility from consumption, X_t, and disutility from the labor supply of each household member, $L_t(j)$. The household maximizes the expected discounted utility function:

$$U_t = E_t\left\{\sum_{k=0}^{\infty}\beta^k\left[\frac{X_{t+k}^{1-\sigma}}{1-\sigma} - \frac{1}{1+\eta}\int_0^1 L_{t+k}(j)^{1+\eta}dj\right]\right\} \quad (1)$$

where $\sigma > 0$ is the coefficient of relative risk aversion, $\eta > 0$ is the inverse Frisch elasticity of labor supply.

[8] Justiniano et al. (2019) consider a closed economy model with exogenous credit supply, whereas Justiniano et al. (2014) consider an open economy model but treats the U.S. trade deficit as an exogenous variable. In the latter, the savings glut gives rise to procyclical house price dynamics which are counterfactual.

[9] Most papers assume that house price expectations are extrapolative (e.g., Adam et al., 2011; Gelain et al., 2018; Glaeser and Nathanson, 2015; Glaeser and Nathanson, 2017). Extrapolative house price expectations would serve as an amplification mechanism for the structural shocks in my model without changing any of my qualitative conclusions.

[10] The assumption of relative impatience of borrowers follows Kiyotaki and Moore (1997).

[11] For the numerical implementation, I use the OccBin toolkit of Guerrieri and Iacoviello (2015).

Aggregate consumption is a composite of non-durable consumption, C_t and housing, H_t:

$$X_t = \left[(1-\alpha) C_t^{\frac{\phi-1}{\phi}} + \alpha H_t^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}} \tag{2}$$

where $\alpha \in (0, 1)$ is the share of housing in aggregate consumption and $\phi > 0$ is the constant elasticity of substitution between non-durable consumption and housing. Housing is assumed to be a non-tradable good, while non-durable consumption are tradable goods, consisting of domestically and foreign produced goods:

$$C_t = \left[(1-\triangle_F)^{\frac{1}{\iota_C}} \left(C_{h,t}\right)^{\frac{\iota_C-1}{\iota_C}} + (\triangle_F)^{\frac{1}{\iota_C}} \left(C_{f,t}\right)^{\frac{\iota_C-1}{\iota_C}} \right]^{\frac{\iota_C}{\iota_C-1}} \tag{3}$$

where $C_{h,t}$ and $C_{f,t}$ are domestically and foreign produced goods, respectively. $\iota_C > 0$ is the elasticity of substitution between domestic and foreign goods, and $\triangle_F \in (0, 1)$ is the share of foreign goods in total non-durable consumption. It is assumed that the consumption of tradable goods exhibit home bias, i.e. $\triangle_F < 0.5$.

Households face the following budget constraint in nominal terms:

$$P_t C_t + Q_t H_t + R_{t-1} B_{t-1} \leq B_t + \int_0^1 W_t(j) L_t(j) dj + Q_t H_{t-1} + DIV_t - T_t$$

where Q_t is the nominal house price, $W_t(j)$ is the nominal wage of the jth household member, DIV_t are nominal dividends from intermediate goods firms, which are owned by households and T_t is a lump-sump tax. B_t is an internationally traded risk-free bond, denoted in domestic currency, and R_t is the gross nominal interest rate.

In real terms (units of non-durable goods) the budget constraint reads:

$$C_t + q_t H_t + R_{t-1} \frac{b_{t-1}}{\Pi_t} \leq b_t + \int_0^1 w_t(j) L_t(j) dj + q_t H_{t-1} + div_t - t_t \tag{4}$$

where q_t is the real house price, b_t is real debt, $\Pi_t = P_t/P_{t-1}$ is the gross inflation rate of consumer prices, $w_t(j)$ is the real wage of worker j, div_t are real dividends and t_t are real lump-sum taxes.

Following Iacoviello (2005), domestic consumers face a collateral constraint which depends on the expected future value of the housing stock:

$$R_t b_t \leq \chi_t E_t(q_{t+1} \Pi_{t+1} H_t) \tag{5}$$

where χ_t is the Loan-To-Value (LTV) ratio, which is assumed to follow a first order autoregressive process in log-deviations from steady state:

$$\hat{\chi}_t = log(\chi_t/\chi) = \rho_\chi \hat{\chi}_{t-1} + \varepsilon_{\chi,t} \tag{6}$$

where $\rho_\chi \in (0, 1)$ and $\varepsilon_{\chi,t}$ ~i.i.d. $\mathcal{N}\left(0, \sigma_\chi^2\right)$.

The optimality conditions of the domestic household read:

$$\lambda_t = MU_t^C, \tag{7}$$

$$\lambda_t q_t = MU_t^H + \beta E_t[\lambda_{t+1}] E_t[q_{t+1}] + \lambda_t^{cc} \chi_t E_t(\Pi_{t+1}) E_t(q_{t+1}), \tag{8}$$

$$\lambda_t = \beta E_t\left[\lambda_{t+1} \frac{R_t}{\Pi_{t+1}}\right] + R_t \lambda_t^{cc}, \tag{9}$$

$$C_{h,t} = (1-\triangle_F)\left(\frac{P_{h,t}}{P_t}\right)^{-\iota_C} C_t, \tag{10}$$

$$C_{f,t} = \triangle_F \left(\frac{\varepsilon_t P_{f,t}^*}{P_t}\right)^{-\iota_C} C_t, \tag{11}$$

$$P_t = \left[(1-\triangle_F)\left(P_{h,t}\right)^{1-\iota_C} + \triangle_F \left(\varepsilon_t P_{f,t}^*\right)^{1-\iota_C} \right]^{\frac{1}{1-\iota_C}} \tag{12}$$

where λ_t and λ_t^{cc} are the Lagrange multipliers on the budget constraint and the collateral constraint, respectively, $P_{f,t}^*$ is the price of foreign goods, denoted in foreign currency, and ε_t is the nominal exchange rate (defined as the price of foreign currency in terms of domestic currency). Note that the law of one price holds, i.e. $\varepsilon_t P_{i,t}^* = P_{i,t}$ for $i = \{h, f\}$. However, due to home bias in consumption, purchasing power parity fails, i.e. $P_t \neq \varepsilon_t P_t^*$, where P_t^* is the foreign price index.

Foreign consumers have the same utility function and face a similar budget constraint as domestic agents. However, due to relative patience, i.e. $\beta < \beta_t^*$, they are net-lenders in international financial markets and do not face a collateral constraint. Foreign consumers' discount factor, β_t^*, is assumed to follow a first order autoregressive process in log-deviations from steady state:

$$\hat{\beta}_t^* = log(\beta_t^*/\beta^*) = \rho_\beta \hat{\beta}_{t-1}^* + \varepsilon_{\beta,t} \tag{13}$$

Labor agencies

I assume that labor agencies, operating under perfect competition, combine differentiated labor inputs from households, $L_t(j)$, according to the following composite:

$$L_t = \left(\int_0^1 L_t(j)^{\frac{\epsilon_w - 1}{\epsilon_w}} dj \right)^{\frac{\epsilon_w}{\epsilon_w - 1}} \tag{14}$$

where ϵ_w is the elasticity of substitution between labor inputs.

The demand for labor input j is given by:

$$L_t(j) = \left(\frac{W_t(j)}{W_t} \right)^{-\epsilon_w} L_t \tag{15}$$

and the aggregate wage index follows from the zero profit condition:

$$W_t = \left(\int_0^1 W_t(j)^{1-\epsilon_w} dj \right)^{\frac{1}{1-\epsilon_w}} \tag{16}$$

Wage setting

Households are monopolistic suppliers of labor. Wages are set on a staggered basis where θ_w is the probability if not being able to reset the wage in the following period. A household which is able to reset its wage in period t maximizes the following expression with respect to the reset wage, $W_t^{reset}(j)$:

$$E_t \left\{ \sum_{k=0}^{\infty} (\theta_w \beta)^k \left[MU_{t+k}^C W_t^{reset}(j) L_{t+k}(j) - \frac{1}{1+\eta} L_{t+k}(j)^{1+\eta} \right] \right\} \tag{17}$$

subject to the demand function (15). The associated wage Phillips curve is given in Appendix A.2.

Firms

Final goods producers combine intermediate goods according to:

$$Y_t = \left(\int_0^1 Y_t(i)^{\frac{\epsilon-1}{\epsilon}} di \right)^{\frac{\epsilon}{\epsilon-1}} \tag{18}$$

Demands for intermediate good i is given by:

$$Y_t(i) = \left(\frac{P_{h,t}(i)}{P_{h,t}} \right)^{-\epsilon} Y_t \tag{19}$$

while the price index for goods produced in the home country follows from the zero profit condition:

$$P_{h,t} = \left(\int_0^1 P_{h,t}(i)^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}} \tag{20}$$

Intermediate goods producers use labor as the only production input:

$$Y_t(i) = AL_t(i) \tag{21}$$

where A is a constant productivity factor.

Prices are set on a staggered basis, where θ is the probability that the firm cannot reset its price in the following period. Firms reset their price to maximize their expected discounted future profits for as long as the reset price is expected to remain in place. This implies that firms maximize the following expression with respect to the reset price, $P_t^{reset}(i)$:

$$E_t \left\{ \sum_{k=0}^{\infty} (\theta \beta)^k MU_{t+k}^C \left[P_{h,t}^{reset}(i) Y_{h,t+k} - W_{t+k} L_{t+k}(i) \right] \right\} \tag{22}$$

subject to (21) and the demand function (19). The associated price Phillips-curve is given in Appendix A.2.

Finally, the housing stock is assumed to be fixed:

$$H_t = H \tag{23}$$

Monetary policy

The monetary authority sets the gross nominal interest rate according to a Taylor (1993a) type rule subject to a zero lower bound restriction:

$$R_t = max\left\{1, R_{t-1}^{\mu_R}\left(\bar{R}\left(\frac{\Pi_{h,t}}{\bar{\Pi}_h}\right)^{\mu_\pi}\left(\frac{Y_t}{Y}\right)^{\mu_Y}\right)^{(1-\mu_R)}\right\} \tag{24}$$

where $\Pi_{h,t}$ is the gross domestic inflation rate, $\bar{\Pi}_h$ is the gross inflation target, and Y is steady state output.[12]

Fiscal policy

The fiscal authority is assumed to follow a balanced-budget rule for government spending:

$$g_t = t_t \tag{25}$$

where real government spending, g_t, is assumed to be strictly directed towards domestically produced goods. For now, I abstract from fiscal policy and simply assume that government spending equals its constant steady state value, g:

$$g_t = g \tag{26}$$

Market clearing

International debt market equilibrium requires that the net supply of bonds is zero:

$$B_t + B_t^* = 0 \tag{27}$$

while goods market clearing requires:

$$Y_t = C_{h,t} + C_{h,t}^* + g_t \tag{28}$$

Equilibrium and steady state

An imperfectly competitive equilibrium of the two-country economy requires that: i) The representative households maximizes utility subject to the budget constraint and the collateral constraint of domestic consumers, taking prices as given. Also, households set the wages on behalf of its members, taking demand for their specific labor variety as given. ii) Intermediate goods producers set their price in order to maximize the present discounted value of profits, taking the demand for their specific goods variety as given. Final goods producers minimize costs given the final output price. iii) Labor and housing markets clear in each country, while goods and financial markets clear internationally.

The assumption $\beta < \beta^*$ gives rise to an asymmetric steady state where the collateral constraint pins down the net foreign assets position. Following Ferrero (2015), the relative productivity level and the housing stock are normalized such that relative prices are equalized across countries and the asymmetry is limited to quantities. Appendix A.1 reports the steady state conditions and Appendix A.2 contains the log-linearized version of the model.

3. Calibration

This section contains the calibration of the model. Unless otherwise noted, parameter values are the same in the two countries.

The foreign discount factor, β^*, is set to 0.99. This implies an annual real interest rate of 4 pct. which roughly corresponds to the actual U.S. short-term real interest rate in 2000.q1. As discussed in Iacoviello and Neri (2010), the value of the borrower's discount factor, β, has to be sufficiently low to ensure that the collateral constraint stays binding at all times. This is satisfied for $\beta = 0.92$.[13] The inverse Frisch elasticity of labor supply, η is set to 2, and the coefficient of relative risk aversion σ is set to 1, implying log-utility. The elasticities of substitution between goods varieties and labor varieties, respectively, are calibrated to match steady state markups of 15 pct. in both goods and labor markets (Woodford, 2003). I set the price and wage stickiness parameters, θ and θ_W, to 0.83, which implies an average duration of price and wage contracts of six quarters. This is somewhat larger than suggested by microeconometric evidence (Nakamura and Steinsson, 2008) but in line with estimates from the DSGE literature (Iacoviello and Neri, 2010). The share of foreign goods in total tradable consumption, $\triangle_F$, is set to 0.2, while the elasticity of substitution between domestic and foreign non-durable consumption

[12] Domestic inflation-targeting (as opposed to CPI inflation-targeting) is a standard assumption in open economy models with complete exchange rate pass-through (e.g., Clarida et al., 2002; Gali and Monacelli, 2005).

[13] In Appendix B, I demonstrate that the model's ability to reproduce the housing boom in Fig. 1 is not particularly sensitive to the choice of β.

goods, ι_C, is set to 0.5, in line with the estimates in, e.g., Lubik and Schorfheide (2005); Taylor (1993b).[14] The elasticity of substitution between consumption and housing, ϕ, is assumed equal to 1, implying a Cobb Douglas specification. Following Monacelli (2009), I set the loan-to-value (LTV) ratio, χ, to 0.75. Then I calibrate the housing share parameter of domestic consumers, α, to match a debt to GDP ratio of 5 percent, which corresponds to one third of the Net International Investment Position of the United States in 2000.q1. This, in turn, roughly corresponds to the share of Treasuries securities and Agency debt to total U.S. securities held by foreigners in 2003 (Bernanke et al., 2011, Table 1). Next I calibrate the foreign housing share, α^*, such that the ratio of consumption to housing wealth is the same in the two countries. Following Ferrero (2015), I calibrate the relative housing stock, H/H^*, such that the relative steady state house price, q/q^*, equals unity. Similarly, I calibrate the productivity ratio, A/A^*, such that the relative price of tradable goods, P_h/P_f^*, equals one.[15] The parameters in the Taylor rule take standard values: The interest smoothing parameter, μ_R, is set to 0.8, whereas the response coefficients, μ_π and μ_Y, are set to 1.5 and 0.5, respectively. The net inflation target is assumed to equal 2.5 percent, in line with the average level of headline CPI inflation over the boom period. The ratio of government spending to output, g/Y, is set equal to 0.25 which approximately corresponds to the U.S. average over the period from 1960 to 2020. Finally, I assume that both the LTV shock and the savings glut shock follow highly persistent processes with autoregressive coefficients, ρ_χ and ρ_β, equal to 0.98.

4. Explaining the boom

4.1. Phase 1: A global savings glut 2000–2003

According to Bernanke's (2005; 2007; 2010) Global Savings Glut Hypothesis, a global excess of desired saving over desired investment, emanating from China and other East Asian economies and the OPEC countries, brought down U.S. mortgage-related interest rates, pushed up the value of the dollar, and helped fuel the housing boom and the deterioration of the current account. A key driver of these capital inflows were official reserve accumulation following the Asian financial crisis of the late 1990's (Bernanke, 2005; 2007; 2010). Underdeveloped financial markets in savings glut countries can help explain why the excess savings flowed towards safe U.S. assets (e.g. Caballero et al., 2008a; Mendoza et al., 2009). In the following, I model the savings glut in a reduced form fashion as a shock to the discount factor of foreign lenders.

Fig. 2 shows the effects of a sequence of shocks to the foreign discount factor which lower the domestic real interest rate from 4 percent in 2000 to nearly 0 percent by 2006. This roughly corresponds to the observed decline in the natural rate of interest in Holston et al. (2017) over the boom-bust cycle.

The increase in foreign savings directly lowers foreign demand for domestically produced goods, leading to a decline in domestic output. Increased foreign demand for domestic bonds lead to a real exchange rate appreciation which amplifies the reduction in domestic output.[16] The decline in domestic production and the appreciation of the exchange rate put a downward pressure on CPI inflation. At the same time, the real interest rates declines, which –all else equal– increases domestic demand for both non-durable consumption and housing. In addition, lower interest rates facilitates borrowing from abroad by relaxing the collateral constraint. As a result, house prices increase and the current account deteriorates.

As Fig. 2 shows, the effects of a savings glut in the model are qualitatively and quantitatively consistent with all of the observed patterns in U.S. data between 2000 and 2003. Notably, the savings glut shocks can fully account for the initial run-up in house prices from 2000 through 2002, which in turn amounts to around half of the total increase in house prices over the 2000–2006 period in the data. The model-implied effects of a savings glut are also in line with the broad macroeconomic implications of a savings glut as described by Bernanke (2005; 2007; 2010). My findings are in line with, e.g., Justiniano et al. (2014, 2019), who show that the savings glut can help explain the dual observation of a reduction in interest rates and a run-up in house prices. To the best of my knowledge, my paper is the first to show that a savings glut gives rise to countercyclical house price dynamics as observed in the U.S. during the early stages of the housing boom. As I demonstrate in Section 6, this finding has crucial implications for policy.

4.2. Phase 2: A Relaxation of domestic borrowing constraints 2003–2006

A large body of literature has linked the U.S. housing boom to a relaxation of borrowing constraints (see, e.g., Favilukis et al., 2017; Ferrero, 2015; Garriga et al., 2019). At the intensive margin, several studies have documented a large decline in loan-to-value requirements during the first half of the 2000′s. For instance, Duca et al. (2011) find that the LTV ratio for first-time home buyers from the American Housing Survey rose from around 88 percent in 2000 to 94 percent in 2006, before declining in 2008. Similarly, Glaeser et al. (2013) find that the median combined LTV ratio on all housing purchases increased from 80 pct. in 2004 to 90 pct. in 2006. Other studies find evidence of even larger increases in LTV ratios (Zimmerman, 2007, 5). At the extensive margin, the growth in subprime lending led to a sizable increase in the share of highly leveraged borrowers (Abraham et al., 2008). Several papers argue that the relaxation of domestic credit standards was endogenously

[14] A relatively low trade elasticity helps my model to generate quantitatively realistic movements in the real exchange rate.

[15] This ensures that the asymmetric steady state is limited to quantities, while prices are the same in the two countries.

[16] The real exchange rate data series shown in Fig. 2 is the exchange rate index vis-a-vis "other important trading partners," which includes most "savings glut countries," such as China and other emerging markets.

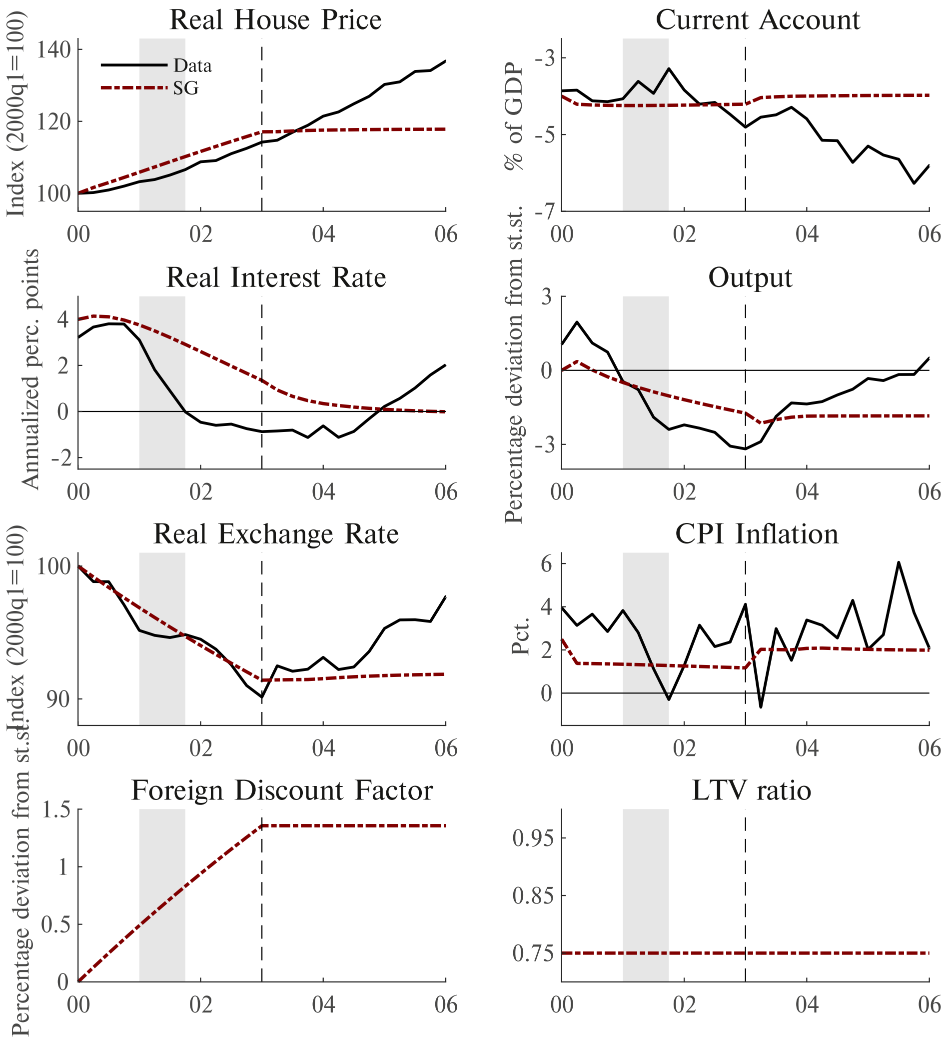

Fig. 2. The effects of a savings glut.

triggered by the inflow of cheap foreign credit stemming from the savings glut (e.g, Bernanke et al., 2011; Caballero and Krishnamurthy, 2009).[17]

The following considers the effects of a relaxation of the borrowing constraint in the model. Specifically, I consider an experiment where the LTV ratio increases from 75% to around 95% between 2003 and 2006. These movements are in line with the empirical evidence described above as well as experiments considered in the existing literature (see, e.g., Favilukis et al., 2017; Garriga et al., 2019; Justiniano et al., 2015; Justiniano et al., 2019). The assumption that the credit liberalization process begins in 2003 is also broadly consistent with empirical evidence.[18] Particularly, Justiniano et al. (2021) provides compelling evidence that the securitization boom took off in the summer of 2003.

Fig. 3 shows the effects of the credit liberalization experiment. The relaxation of borrowing constraints allows domestic households to borrow more and increase their consumption of both non-durable goods and housing. Moreover, the shock drives up the real value of the housing stock as this serves as collateral for foreign debt. This leads to an increase in house prices and domestic production as well as a rising current account deficit. At the same time, the credit liberalization puts

[17] Caballero and Krishnamurthy (2009) and Bernanke et al. (2011) find that the increase in credit supply created its own demand via the securitization process. In my model, savings glut shocks and LTV shocks are orthogonal to each other. However, the increase in the model-implied LTV ratio in Fig. 3 is clearly preceeded by an increase in the foreign discount factor, lending informal support to this hypothesis.

[18] Duca et al. (2011) documents a dramatic rise in the LTV ratios of first time home-buyers between 2002 and 2005, while Abraham et al. (2008) documents that the share of subprime borrowers rose sharply between 2004 and 2005. Note, however, that my model does *not* rule out a loosening of collateral constraints before 2003. However, the decline in interest rates observed over this period implies that the effects of the savings glut must have exceeded the effects of looser collateral requirements on the equilibrium interest rate.

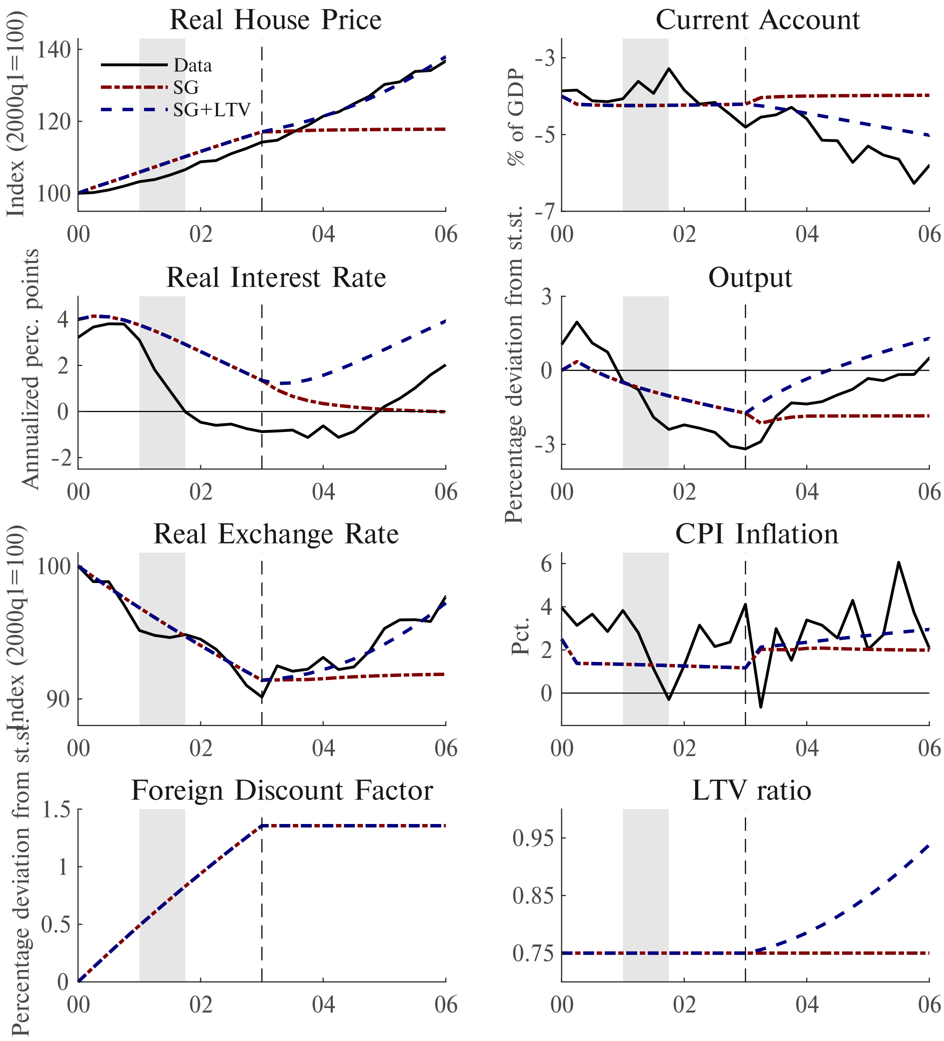

Fig. 3. The effects of a savings glut followed by a relaxation of borrowing constraints.

an upward pressure on interest rates as it raises domestic demand for foreign credit. Accordingly, the real exchange rate depreciates. The exchange rate depreciation and the increase in domestic production serve to raise CPI inflation.

As evident from Fig. 3, all of the patterns described above are consistent with U.S. data between 2003 and 2006. Thus, a liberalization of domestic credit standards provides a plausible explanation to the sustained boom in U.S. house prices from 2003 to 2006, including the positive co-movement between house prices, output and the real interest rate observed in the data. These results are in line with Ferrero (2015) and several other papers that find that relaxed borrowing constraints played a key role in fueling the housing boom (e.g., Favilukis et al., 2017; Garriga et al., 2019).

5. Explaining the bust: A tightening of domestic borrowing constraints 2007–2010

Which shock can explain the house price collapse between 2007 and 2010 in the model? As demonstrated in the previous section, shocks to the LTV ratio generate positive co-movement between house prices, output and the real interest rate. As Fig. 1 shows, this pattern matches U.S. data during the boom period from 2003 to 2006. Importantly, however, it also matches the data during the subsequent bust from 2007 through 2009. As shown in Fig. 4, house prices, output and the real interest rate all declined sharply during the Great Recession. Indeed, empirical evidence shows that the housing market bust was associated with a large contraction in LTV ratios (Duca et al., 2011) and a sharp rise in mortgage default rates (Mian and Sufi, 2009).

Fig. 4 illustrates the effects of a liberalization and subsequent tightening of domestic credit standards. As in the previous experiment, the LTV ratio increases from 75% to around 95% between 2003 and 2006. Between 2007 and 2010, the LTV ratio reverts back to its initial level, as suggested by empirical evidence (Duca et al., 2011). Fig. 4 shows that a contraction in borrowing constraints generates a house price collapse, sharp and sustained drops in both output and the real interest

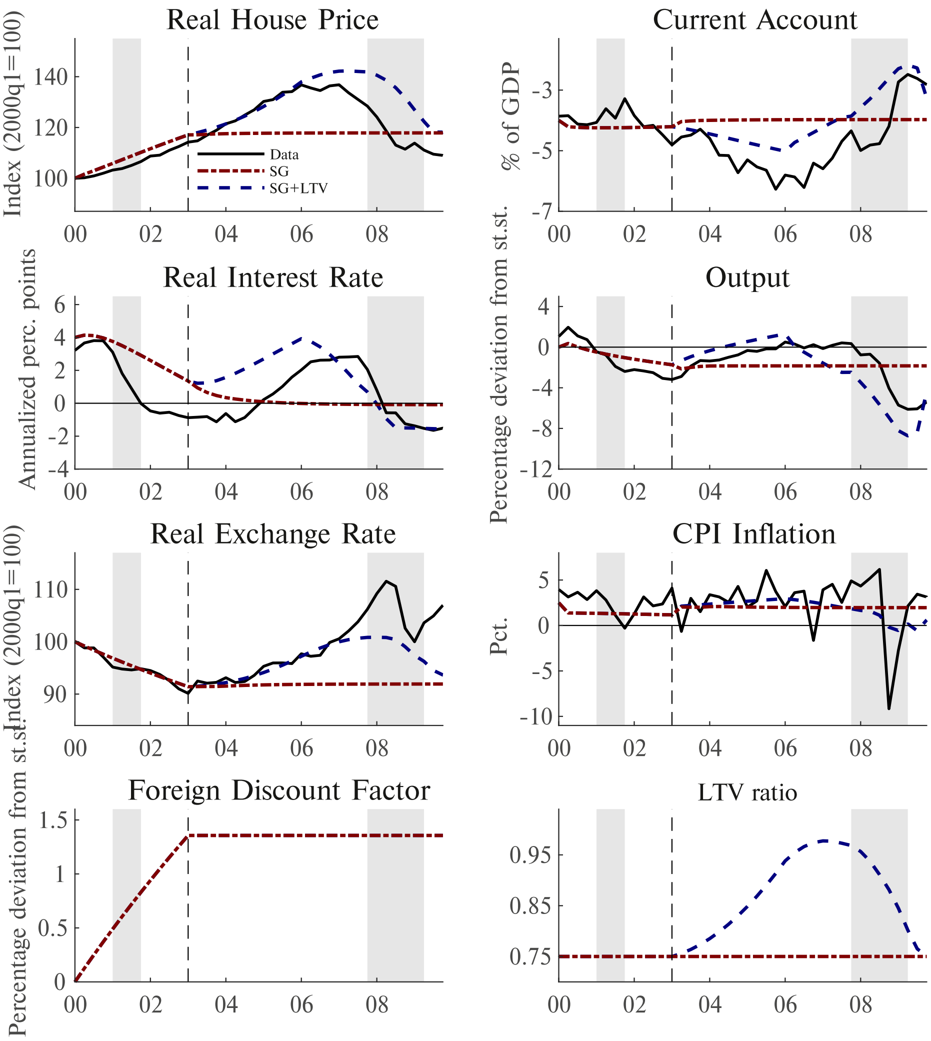

Fig. 4. The effects of a savings glut followed by a relaxation and subsequent tightening of borrowing constraints.

rate as well as a rapid current account improvement.[19] All of these patterns are –qualitatively and quantitatively– consistent with the developments in the data over the period from 2007 to 2010. Thus, according to the model, the fundamental driver of the housing market bust was a tightening of domestic borrowing constraints.

6. Policy response to the housing boom

Could policymakers have prevented the housing boom? Specifically, can policymakers stabilize house prices without violating the Fed's dual mandate of maintaining price stability and maximum employment? In an attempt to answer this question, this section investigates the effects of various policies on house prices and other key variables in the model over the boom period from 2000 to 2006. Section 6.1 investigates whether the domestic central bank could have counteracted the house price boom by responding directly to house price appreciation. Section 6.2 analyzes the effects of macroprudential policy in the form of a countercyclical LTV-ratio. Finally, Section 6.3 considers the implications of countercyclical government spending.

6.1. Monetary policy response to house prices

Whether or not the central bank should actively respond to movements in asset prices has been the subject of a longstanding debate (Adam et al., 2021; Bernanke and Gertler, 2001; Rudebusch, 2005). To investigate the implications of such a

[19] In the model, the domestic zero lower bound becomes binding in 2009.q1. Fig. C.1 in Appendix C shows that the binding zero lower bound serves to amplify the declines in domestic output and house prices.

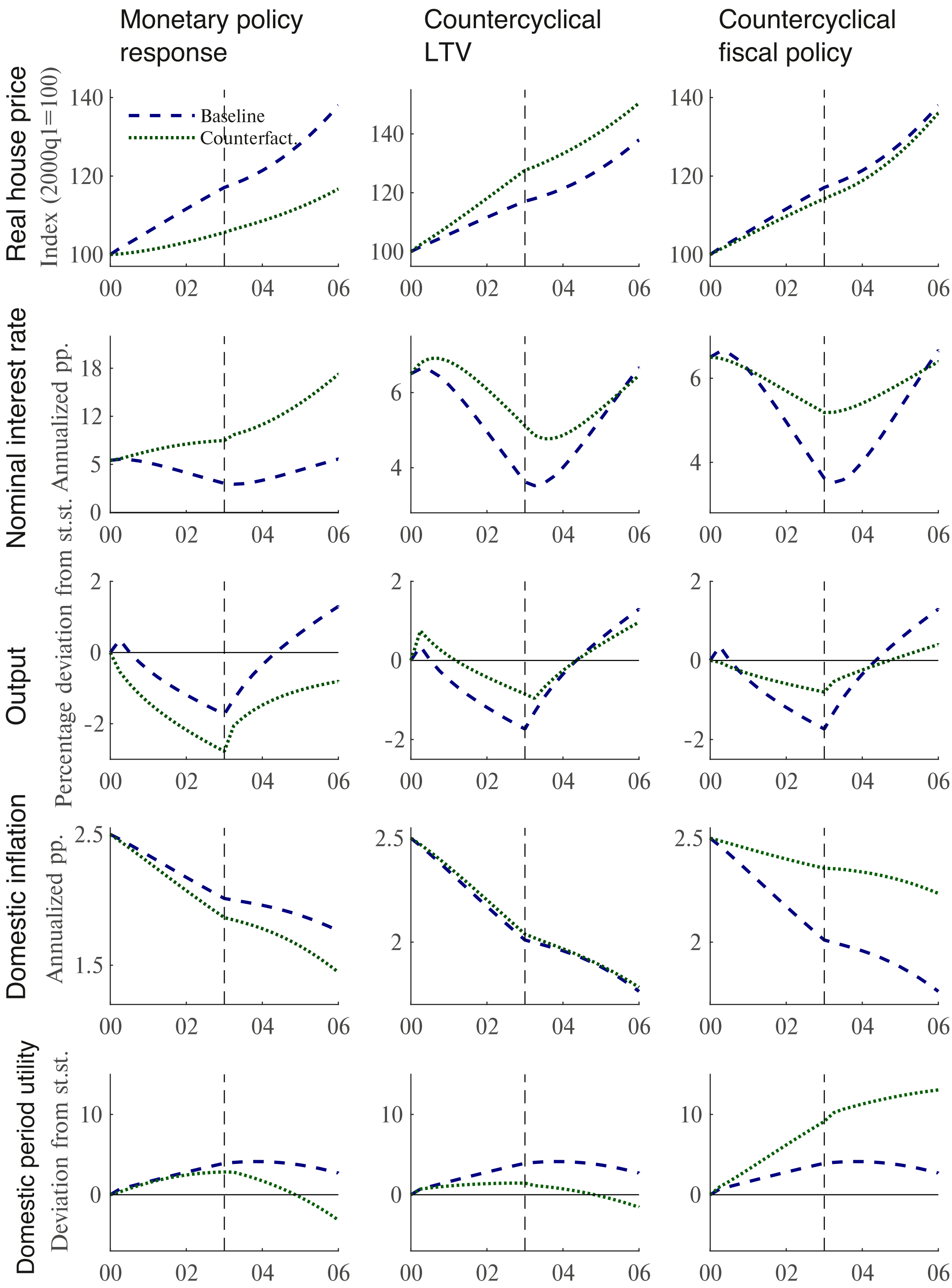

Fig. 5. Counterfactual responses of macroeconomic variables under alternative policies.

policy, assume that the domestic central bank sets it interest rate according to the following log-linearized policy rule which allows for a positive response to house price appreciation:

$$\hat{R}_t = max\left\{-log(\Pi_h/\beta^*),\ \mu_R\hat{R}_{t-1} + (1-\mu_R)\left[\mu_\pi\pi_{h,t} + \mu_Y\hat{Y}_t + \mu_q\Delta\hat{q}_t\right]\right\} \tag{29}$$

where $\mu_q > 0$ and $\Delta\hat{q}_t$ is the quarterly house price growth rate.

Given the paths of the foreign discount factor and the LTV ratio, respectively, shown in Fig. 3, I calibrate μ_q such that house prices increase by half as much as they do in Fig. 3 between 2000 and 2006. This is satisfied for $\mu_q = 3.5$.

The results of this exercise are shown in the first column in Fig. 5. The baseline scenario corresponds to the simulation with both savings glut shocks and LTV shocks shown in Fig. 3, while the counterfactual scenario corresponds to a simulation with the same sequences of shocks but with the augmented Taylor rule (29). As Fig. 5 illustrates, a positive monetary policy response to house prices implies that the central bank raises the nominal interest rate compared to the baseline simulation, counteracting the downward pressure from the savings glut shocks. A higher interest rate dampens the boom in house prices. However, it also serves to amplify the declines in domestic output and inflation. Given that the central bank seeks to stabilize domestic inflation and output, this outcome may not be desirable from a policy perspective.

From a welfare perspective, the policy may also not be feasible. As shown in the bottom left panel of Fig. 5, the period utility of domestic consumers declines compared to the baseline scenario. The intuition is straightforward: Higher interest rates dampen the housing boom and depress domestic consumption. Output declines as well, leading to a reduction in labor supply. Nonetheless, domestic utility declines in equilibrium.[20]

6.2. Countercyclical LTV-ratio

Assume instead that policymakers introduce a countercyclical LTV-ratio to dampen the house price boom, as proposed by, e.g., Basel Committee on the Global Financial System (2010) and IMF (2011). Specifically, Eq. (6) is replaced by the following expression which allows for a systematic response of the LTV ratio to log-deviations of output from its steady state value:

$$\hat{\chi}_t = \rho_\chi \hat{\chi}_{t-1} - \Phi_\chi \hat{Y}_t + \varepsilon_{\chi t} \tag{30}$$

where $\Phi_\chi > 0$.

Given the baseline paths of the foreign discount factor and the LTV ratio, respectively, shown in Fig. 3, I calibrate Φ_χ such that output declines by half as much as in the baseline simulation between 2000 and 2003.[21] This is satisfied for $\Phi_\chi = 0.4$. The results of this exercise are shown in the second column in Fig. 5.

As Fig. 5 shows, a countercyclical LTV ratio serves to *increase* house prices in equilibrium. On the one hand, the savings glut lowers domestic output, in which case Eq. (30) implies that the borrowing constraint should be relaxed. All else equal, this serves to amplify the boom in house prices. On the other hand, a countercyclical LTV ratio serves to dampen the effects of LTV shocks on the equilibrium LTV ratio and thus on house prices. As Fig. 5 shows, the former effect dominates the latter. This is because the savings glut pushes the output gap persistently into negative territory. Thus, according to the model, a countercyclical LTV ratio would have amplified the housing boom, instead of preventing it, contrary to conventional wisdom (e.g., Basel Committee on the Global Financial System, 2010 and IMF, 2011). Moreover, as shown in the bottom middle panel of Fig. 5, a countercyclical LTV ratio lowers domestic flow utility. Similarly, shocks to the LTV ratio reduce domestic utility in the baseline simulation over the 2003–2006 period. The finding relies heavily on the assumption of a low trade elasticity, ι_C.[22] A relaxation of lending standards serves to amplify the boom in house prices and domestic consumption. At the same time, however, higher domestic output implies an increase in labor supply, which –all else equal– lowers domestic utility. When the trade elasticity is low, a relaxation of lending standards induce a large exchange rate depreciation, which in turn leads to a large decline in the real wage. This puts a downward pressure on domestic consumption, lowering domestic utility in equilibrium.

6.3. Countercyclical government spending

As a final alternative, assume that the domestic fiscal authority, in place of Eq. (26), follows a countercyclical policy rule for government spending, which, in log-linear form, reads:

$$\hat{g}_t = -\Phi_g \hat{Y}_t \tag{31}$$

where $\Phi_g > 0$. Again, taking the baseline sequence of discount factor and LTV shocks from Fig. 3 as given, I calibrate the parameter Φ_g such that output declines by half as much as in the baseline simulation between 2000 and 2003. This is satisfied for $\Phi_g = 9$.

The results of this exercise are shown in the third column in Fig. 5. Because the savings glut lowers the output gap over the entire boom period, the policy rule (31) generally implies an increase in both government spending and taxes. As Fig. 5 shows, this serves to stabilize house prices, output and domestic inflation over the entire boom period. Intuitively, government spending on domestically produced goods increases domestic output and inflation. At the same time, higher interest rates tighten the collateral constraint, which in turn lowers domestic demand for housing, thus dampening the house price boom.[23] The increase in output and domestic inflation puts an upward pressure on the domestic nominal interest

[20] On the other hand, a monetary response to house prices movements does *not* prevent domestic consumption from declining during the subsequent housing market bust because policy is constrained by the zero lower bound. These results are available upon request.

[21] Note that it is *not* possible to calibrate the three policy parameters in this section ($\mu_q > 0$, $\Phi_\chi > 0$, and $\Phi_g > 0$) to generate identical responses of a single variable, say house prices, in all three policy experiments.

[22] A low value of ι_C is in turn crucial in explaining the real exhange rate movements shown in Figure 4.

[23] While the quantitative effects on house prices in Fig. 5 are modest, larger effects would be obtained with a higher value of Φ_g.

rate, pushing the economy away from the zero lower bound. Thus, countercyclical government spending appears to resolve most of the policy trade-offs associated with the savings glut. In addition, as shown in the bottom right panel of Fig. 5, countercyclical government spending raises domestic utility substantially compared to the baseline scenario. This result is interesting as government spending itself is wasteful in the model and fully funded through domestic taxation. Again, the finding relies on the assumption of a low trade elasticity, ι_C. Intuitively, an increase in government spending leads to higher domestic interest rates, yielding an exchange rate appreciation which –all else equal– raises the domestic real wage. When the trade elasticity is low, the exchange rate appreciation and the associated rise in the real wage are large, leading to an equilibrium increase in domestic consumption and flow utility.[24]

7. Conclusion

An increase in foreign credit supply (a savings glut) triggered the U.S. housing boom in the early 2000′s. I base this conclusion on an open economy model with housing and collateralized foreign debt. In the model, a savings glut shock can account for six observations in U.S. data over the period from 2000 through 2002: 1) the increase in house prices, 2) the decline in the real interest rate, 3) the current account deterioration, 4) the real exchange rate appreciation, 5) the decline in output and, 6) the decline in inflation. The effects of relaxed borrowing constraints are qualitatively at odds with several of these observations. Changes in credit restrictions can, however, help explain the procyclical boom-bust pattern in U.S. data from 2003 to 2010, including the positive co-movement between house prices, output and the real interest rate observed over this period.

The Global Savings Glut Hypothesis (Bernanke, 2005; 2007; 2010) offers a coherent explanation to several macroeconomic trends in recent decades, including the downward drift in interest rates and the increase in asset price volatility, as observed in the U.S. and elsewhere. It therefore draws a link between important –though seemingly unrelated– policy questions, such as 1) should policy respond to asset price fluctuations? and 2) what policy can help the economy escape a liquidity trap? In the model, a savings glut shock increases house prices but lowers domestic output and inflation. Thus, when setting the nominal interest rate, the domestic central bank faces a trade-off between stabilizing house prices, on the one hand, and stabilizing output and inflation, on the other hand. Macroprudential policy in the form of a countercyclical LTV-ratio does not resolve this trade-off because the negative response of output to the savings glut shock implies that borrowing constraints should be *relaxed* in response to the shock. While this serves to dampen the declines in inflation and output, it amplifies the house price boom. Thus, neither monetary nor macroprudential policy appear desirable when the economy is subject to a savings glut. Instead, as I demonstrate, countercyclical government spending financed by a lump sum tax stabilizes house prices, output and domestic inflation over the entire boom period, pushes the economy away from the zero lower bound, and raises domestic utility.

Data availability

Data will be made available on request.

Appendix A. The model

A1. Steady state

The steady state of the model can be summarized by the following system of equations:

$$X = \left[(1-\alpha)C^{\frac{\phi-1}{\phi}} + \alpha H^{\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}} \tag{A.1}$$

$$X^* = \left[(1-\alpha)C^{*\frac{\phi-1}{\phi}} + \alpha H^{*\frac{\phi-1}{\phi}}\right]^{\frac{\phi}{\phi-1}} \tag{A.2}$$

$$Y = (1-\triangle_F)C + \triangle_F C^* + g \tag{A.3}$$

$$Y^* = (1-\triangle_F)C^* + \triangle_F C + g^* \tag{A.4}$$

$$Y^\eta = A^{1+\eta}\frac{\epsilon-1}{\epsilon}(1-\alpha)X^{\frac{1}{\phi}-\sigma}C^{-\frac{1}{\phi}} \tag{A.5}$$

[24] During the subsequent downturn, however, countercyclical government spending does *not* raise domestic consumption substantially compared to the baseline scenario. Intuitively, government spending only raises the domestic interest rate slightly above the zero lower bound in the counterfactual simulation. Therefore, its effects on the exchange rate and the real wage are relatively muted over the 2007–2010 period. These results are available upon request.

$$Y^{*\eta} = A^{*1+\eta}\frac{\epsilon - 1}{\epsilon}(1-\alpha)X^{*\frac{1}{\phi}-\sigma}C^{*-\frac{1}{\phi}} \tag{A.6}$$

$$q = \frac{\alpha}{1-\alpha}\frac{1}{1-\beta-\chi(\beta^* - \beta)}\left(\frac{C}{H}\right)^{\frac{1}{\phi}} \tag{A.7}$$

$$q^* = \frac{\alpha}{1-\alpha}\frac{1}{1-\beta^*}\left(\frac{C^*}{H^*}\right)^{\frac{1}{\phi}} \tag{A.8}$$

$$C + b\left(\frac{1}{\beta^*} - 1\right) = Y - g \tag{A.9}$$

$$b = \beta^* \chi q H \tag{A.10}$$

A2. Log-linearized model

Optimality conditions of domestic consumers:

$$\hat{q}_t = \frac{1}{\phi}\hat{C}_t + \beta\left[\left(\frac{1}{\phi} - \sigma\right)\left(\hat{X}_{t+1} - \hat{X}_t\right) - \frac{\mathbf{1}}{\phi}\hat{C}_{t+1} + \hat{q}_{t+1}\right] \tag{B.1}$$

$$+\chi(\beta^* - \beta)\left(\lambda_t^{\hat{c}c} + \hat{\chi}_t + \pi_{t+1} + \hat{q}_{t+1} - \left(\frac{1}{\phi} - \sigma\right)\hat{X}_t\right)$$

$$\frac{1}{\phi}\hat{C}_t = -\hat{R}_t + \left(\frac{1}{\phi} - \sigma\right)\hat{X}_t + \frac{\beta}{\beta^*}\left[\frac{1}{\phi}\hat{C}_{t+1} - \left(\frac{1}{\phi} - \sigma\right)\hat{X}_{t+1} + \pi_{t+1} + \hat{\lambda}_t^{cc}\right] - \hat{\lambda}_t^{cc} \tag{B.2}$$

$$\hat{C}_{h,t} = -\iota_C\hat{p}_{h,t} + \hat{C}_t \tag{B.3}$$

$$\hat{C}_{f,t} = -\iota_C\left(\hat{\Gamma}_t + \hat{p}_{h,t}\right) + \hat{C}_t \tag{B.4}$$

$$\hat{p}_{h,t} = -\triangle_F\hat{\Gamma}_t \tag{B.5}$$

where

$$\hat{X}_t = (1-\alpha)\left(\frac{C}{X}\right)^{\frac{\phi-1}{\phi}}\hat{C}_t \tag{B.6}$$

Domestic budget constraint:

$$\hat{C}_t = \frac{Y}{C}\left(\hat{Y}_t + \hat{p}_{h,t}\right) + \frac{b}{C}\left[\hat{b}_t - \frac{1}{\beta^*}\left(\hat{b}_{t-1} + \hat{R}_{t-1} - \pi_t\right)\right] - \frac{g}{C}\hat{g}_t \tag{B.7}$$

Domestic borrowing constraint:

$$\hat{b}_t = \hat{\chi}_t + \hat{q}_{t+1} - \left(\hat{R}_t - \pi_{t+1}\right) \tag{B.8}$$

Domestic wage setting:

$$\pi_{w,t} = \beta\pi_{w,t+1} + \kappa_w\left[\eta\hat{L}_t - \left(\frac{1}{\phi} - \sigma\right)\hat{X}_t + \frac{1}{\phi}\hat{C}_t - \hat{w}_t\right] \tag{B.9}$$

where $\kappa_w = \frac{(1-\theta_w)(1-\beta\theta_w)}{\theta_w(1+\epsilon_w\eta)}$ and

$$\pi_{w,t} = \hat{w}_t - \hat{w}_{t-1} + \pi_t \tag{B.10}$$

Domestic production and price setting:

$$\hat{Y}_t = \hat{L}_t \tag{B.11}$$

$$\pi_{h,t} = \beta E_t\pi_{h,t+1} + \kappa\hat{mc}_t \tag{B.12}$$

where $\kappa = \frac{(1-\theta)(1-\beta\theta)}{\theta}$ and

$$\hat{mc}_t = \hat{w}_t - \hat{p}_{h,t} \tag{B.13}$$

Domestic fiscal policy:

$$\hat{g}_t = 0 \tag{B.14}$$

Domestic monetary policy:

$$\hat{R}_t = max\left\{-log(\Pi_h/\beta^*), \mu_R\hat{R}_{t-1} + (1-\mu_R)\left[\mu_\pi\pi_{h,t} + \mu_Y\hat{Y}_t\right]\right\} \tag{B.15}$$

Optimality conditions of foreign consumers:

$$\hat{q}_t^* = \frac{1}{\phi}\hat{C}_t^* + \beta^*\left[\hat{\beta}_t^* + \left(\frac{1}{\phi} - \sigma\right)\left(\hat{X}_{t+1}^* - \hat{X}_t^*\right) - \frac{1}{\phi}\hat{C}_{t+1}^* + \hat{q}_{t+1}^*\right] \tag{B.16}$$

$$\frac{1}{\phi}\hat{C}_t^* = \frac{1}{\phi}\hat{C}_{t+1}^* - \left(\frac{1}{\phi} - \sigma\right)\left(\hat{X}_{t+1}^* - \hat{X}_t^*\right) - \left(\hat{R}_t - \pi_{t+1}^* - \triangle\hat{\varepsilon}_{t+1} + \hat{\beta}_t^*\right) \tag{B.17}$$

$$\frac{1}{\phi}\hat{C}_t^* = \frac{1}{\phi}\hat{C}_{t+1}^* - \left(\frac{1}{\phi} - \sigma\right)\left(\hat{X}_{t+1}^* - \hat{X}_t^*\right) - \left(\hat{R}_t^* - \pi_{t+1}^* + \hat{\beta}_t^*\right) \tag{B.18}$$

$$\hat{C}_{h,t}^* = -\iota_C\left(-\hat{\Gamma}_t + \hat{p}_{f,t}^*\right) + \hat{C}^* \tag{B.19}$$

$$\hat{C}_{f,t}^* = -\iota_C\hat{p}_{f,t}^* + \hat{C}^* \tag{B.20}$$

$$\hat{p}_{f,t}^* = \triangle_F\hat{\Gamma}_t \tag{B.21}$$

where

$$\hat{X}_t^* = (1-\alpha)\left(\frac{C^*}{X^*}\right)^{\frac{\phi-1}{\phi}}\hat{C}_t^* \tag{B.22}$$

Foreign wage setting:

$$\pi_{wt}^* = \beta^*\pi_{wt+1}^* + \kappa_w^*\left[\eta\hat{L}_t^* - \left(\frac{1}{\phi} - \sigma\right)\hat{X}_t^* + \frac{1}{\phi}\hat{C}_t^* - \hat{w}_t^*\right] \tag{B.23}$$

where $\kappa_w^* = \frac{(1-\theta_w)(1-\beta^*\theta_w)}{\theta_w(1+\epsilon_w\eta)}$ and

$$\pi_{wt}^* = \hat{w}_t{}^* - \hat{w}_{t-1}^* + \pi_t^* \tag{B.24}$$

Foreign production and price setting:

$$\hat{Y}_t^* = \hat{L}_t^* \tag{B.25}$$

$$\pi_{f,t}^* = \beta^* E_t\pi_{f,t+1}^* + \kappa^*\hat{mc}_t^* \tag{B.26}$$

where $\kappa^* = \frac{(1-\theta)(1-\beta^*\theta)}{\theta}$ and

$$\hat{mc}_t^* = \hat{w}_t^* - \hat{p}_{f,t}^* \tag{B.27}$$

Foreign fiscal policy:

$$\hat{g}_t^* = 0 \tag{B.28}$$

Foreign monetary policy:

$$\hat{R}_t^* = max\left\{-log\left(\Pi_f^*/\beta^*\right), \mu_R\hat{R}_{t-1}^* + (1-\mu_R)\left[\mu_\pi\pi_{f,t}^* + \mu_Y\hat{Y}_t^*\right]\right\} \tag{B.29}$$

Goods market equilibria:

$$\hat{Y}_t = \frac{C_h}{Y}\hat{C}_{h,t} + \frac{C_h^*}{Y}\hat{C}_{h,t}^* + \frac{g}{Y}\hat{g}_t \tag{B.30}$$

$$\hat{Y}_t^* = \frac{C_f^*}{Y^*}\hat{C}_{f,t}^* + \frac{C_f}{Y^*}\hat{C}_{f,t} + \frac{g^*}{Y^*}\hat{g}_t^* \tag{B.31}$$

Nominal exchange rate

$$\hat{\Gamma}_t - \hat{\Gamma}_{t-1} = \triangle\hat{\varepsilon}_t + \pi_{f,t}^* - \pi_{h,t} \tag{B.32}$$

CPI inflation rates:

$$\pi_t = \pi_{h,t} - \triangle\hat{p}_{h,t} \tag{B.33}$$

$$\pi_t^* = \pi_{f,t}^* - \triangle\hat{p}_{f,t}^* \tag{B.34}$$

Real exchange rate:

$$\triangle s_t = \triangle\hat{\varepsilon}_t + \pi_t^* - \pi_t \tag{B.35}$$

Domestic current account:

$$CA_t = \frac{b}{Y}\left(\hat{b}_t - \hat{b}_{t-1} + \pi_t\right) \tag{B.36}$$

where CA_t is the current account normalized by steady state output.

Domestic LTV ratio:

$$\hat{\chi}_t = \rho_\chi \hat{\chi}_{t-1} + \varepsilon_{\chi t} \tag{B.37}$$

Foreign discount factor:

$$\hat{\beta}_t^* = \rho_\beta \hat{\beta}_{t-1}^* + \varepsilon_{\beta t} \tag{B.38}$$

Appendix B. Robustness: Borrowing country discount factor

This section analyzes the quantitative importance of a key model parameter, namely the value of the domestic discount factor β, in explaining the house price boom in Section 4. Ferrero (2015) shows that the quantitative importance of LTV shocks in his model depends crucially on the value of β. Specifically, lower values of β imply larger effects of LTV shocks on house prices.

Fig. B.1 below shows the response of house prices to the combination of savings glut shocks and LTV shocks from the baseline simulation in Fig. 3 for two different values of the discount factor β (for convenience, I have reproduced the baseline paths of the foreign discount factor and the LTV ratio in the two lower panels in Fig. B.1). The simulation with $\beta = 0.92$ corresponds to the baseline simulation from Fig. 3 ("SG+LTV"), whereas the alternative simulation assumes a considerably lower value of the discount factor, namely $\beta = 0.85$.

As shown in the upper right panel in Fig. B.1, $\beta = 0.92$ is the *highest* possible value of the borrowing country discount factor that is compatible with maintaining a binding collateral constraint in the model given the baseline calibration in Section 3 and the baseline sequence of shocks.[25] Importantly, however, as shown in the upper left panel in Fig. B.1, the value of the discount factor does not matter much for the size of the house price boom produced by the model. Specifically, for $\beta = 0.92$, house prices increase by 38 percent over the period, whereas they increase by 41 percent when $\beta = 0.85$. Intuitively, a lower value of the discount factor amplifies the effects of LTV shocks but *dampens* the effects of savings glut shocks. This is also evident from Fig. B.1: When the discount factor is low, house prices increase *less* during the initial boom period from 2000 through 2002 (when house prices are driven by savings glut shocks) but *more* during the subsequent period from 2003 through 2005 (when house prices are driven by LTV shocks). Thus, the value of the domestic discount factor merely helps determine the relative importance of savings glut shocks relative to LTV shocks in driving house prices.

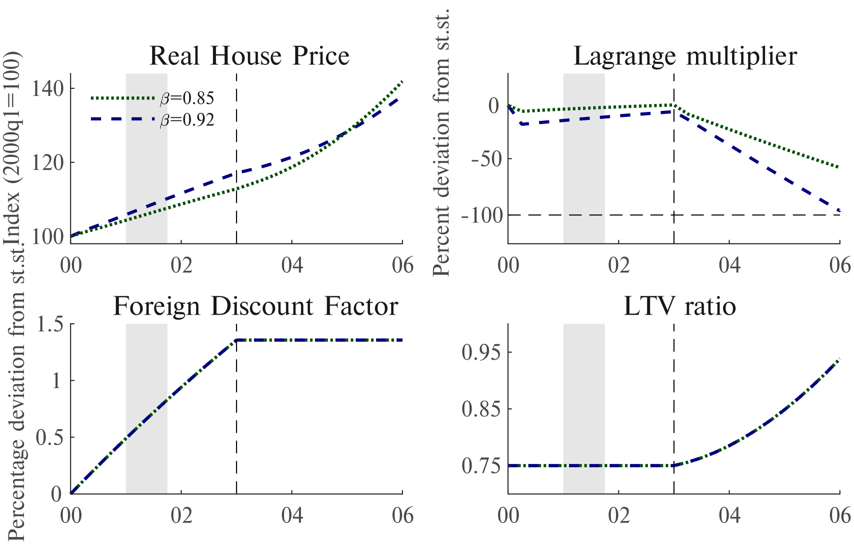

Fig. B.1. Robustness: The value of the borrowing country discount factor.

[25] The Lagrange multiplier increases after 2006.q1 (not shown in Fig. B.1), hence the collateral constraint never seizes to bind in the model.

Appendix C. The role of the ZLB

Fig. C.1 compares the responses of the model to savings glut shocks and LTV shocks with and without, respectively, zero lower bound restrictions on the nominal interest rates in the two countries. As shown, the domestic zero lower bound becomes binding in 2009.q1 in the model. All else equal, this serves to amplify the declines in both domestic output and house prices, though the quantitative effects on house prices are small.

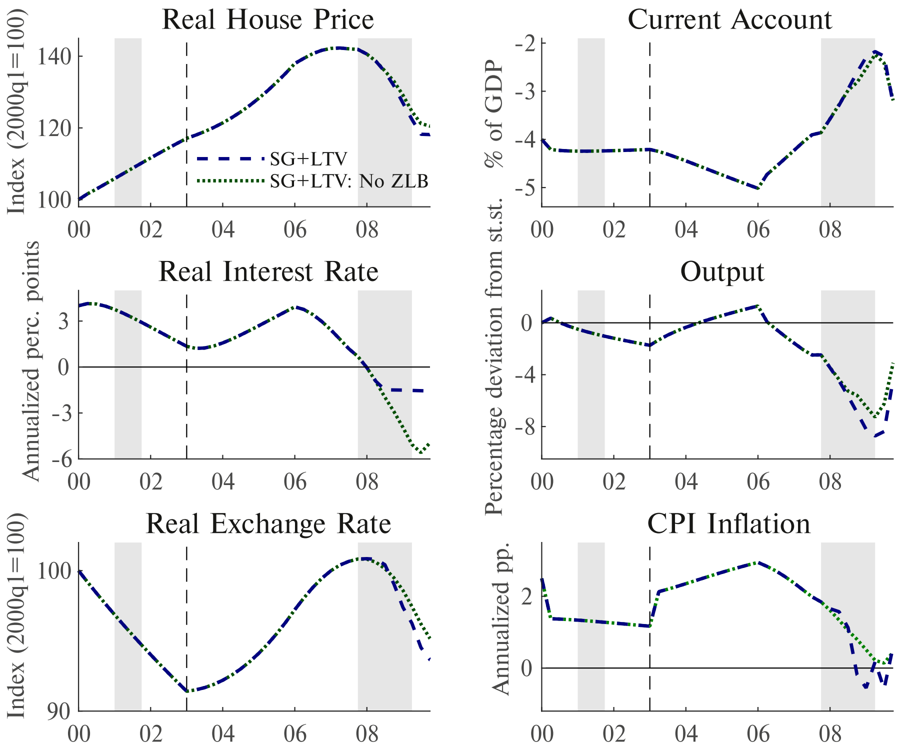

Fig. C.1. The role of the ZLB.

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