House Price Booms, Current Account Deficits, and Low Interest Rates*

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Abstract

Domestic factors, such as credit and preference shocks, can explain the negative correlation between house price prices current account balances observed in the United States and several other countries before the recent crisis. These shocks, however, cannot account for the fall of the real interest rate observed in the data. Expansionary monetary policy shocks in the United States, coupled with exchange rate pegs to the dollar in emerging economies, are crucial to understand the evolution of the real interest rate. Yet, monetary policy factors play virtually no role for house prices and the current account.

Keywords: borrowing constraints, monetary policy shocks, exchange rate pegs

JEL codes: E52, E58, F32, F41

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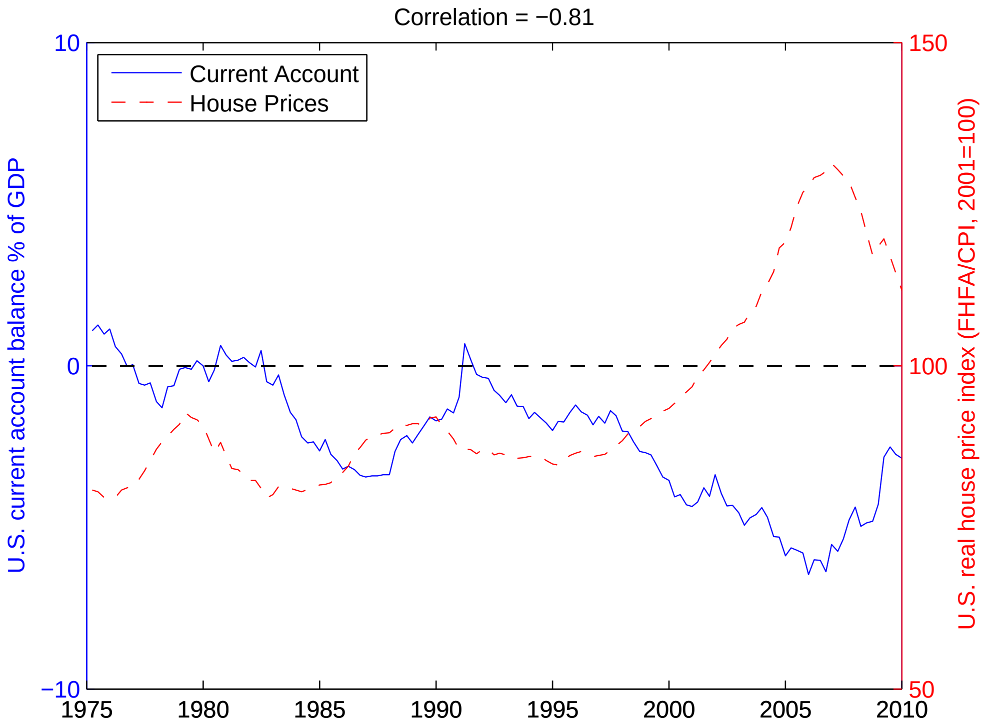

Figure 1: U.S. current account balance % of GDP (left axis) and FHFA existing one-family house price index deflated by headline CPI (right axis, 2001 = 100). Source: Bureau of Economic Analysis, Federal Housing Finance Agency and author's calculations.

1 Introduction

The boom-bust in U.S. house prices has been a fundamental determinant of the recent financial crisis. The securitization process that eventually led the international financial system on the brink of collapse crucially relied on expectations of ever-increasing house prices. Understanding the causes of house price dynamics is then crucial for preventing a repeat of a similar situation in the future.

At a first pass, a key distinction to make progress in this direction is to ascertain whether domestic or foreign factors should form the main basis for a candidate explanation of the housing cycle. In this respect, the current consensus appears to be that some variation of the so-called "global saving glut" hypothesis (Bernanke, 2005) can account for the joint observation that increasing house prices were accompanied by an influx of foreign money into the United States, starting in the late 1990s until the mid 2000s (Figure 1).[1] Building on their earlier

[1] Ahearne et al. (2005) document the co-movement between between house prices and external imbalances since 1970. In Aizenman and Jinjarak (2009), a one standard deviation increase in lagged current account deficits is associated with a 10% appreciation of real estate prices. Kole and Martin (2009) find only slightly smaller elasticities.

work, Caballero et al. (2008b) formalize this argument, showing that a global demand for liquidity can generate capital flows from the rest of the world toward the U.S., where asset prices—and especially house prices, due to the securitization process—take off.

The first result in this paper is to demonstrate that domestic factors (credit and preference shocks) also have the potential to generate the full boom in house prices observed in the data, as well as a non-negligible portion of the deterioration in the balance of the current account. This approach, however, gives rise to a counterfactual evolution of the real interest rate. Perhaps for this reason, the existing literature that focuses on domestic factors to account for the house price boom has also made use, more or less explicitly, of the global saving glut hypothesis, as to render the models consistent with the evidence on real interest rates (Favilukis et al., 2011; Boz and Mendoza, 2010).

This paper abstracts from saving glut shocks and suggests a different explanation for low interest rates, which relies on expansionary monetary policy in the U.S. and a regime of fixed exchange rates in the rest of the world. Importantly, credit and preference shocks remain the main driver of house price and current account dynamics, with monetary factors only playing a minor role. The main result of the paper, therefore, is a dichotomy between the fundamental factors that explain house prices and the current account (credit and preference shocks), and those that explain the real interest rate (monetary policy shocks and foreign peg). Obviously, these findings do not disprove, but rather complement, the role of the global saving glut hypothesis in accounting for the correlation between the house price boom and the deterioration of the current account in the U.S. during the early 2000s.

Figure 1 plots the evolution of U.S. real house prices (dashed red line, right scale) and balance on the current account in % of GDP (continuous blue line, left scale). At the same time as house prices soared, posting a 30% increase between 2001 and 2006, the U.S. current account reached an unprecedented deficit of more than 6% of GDP in mid 2006. These two variables were perhaps the most discussed indicators of U.S. imbalances (Greenspan, 2005). Interestingly, the negative correlation between house price dynamics and current account balances is not specific to the U.S. but rather a robust global phenomenon, affecting advanced and emerging market economies alike (Figure 2).[2] Countries that witnessed the largest house prices booms and current account deficits (such as Greece, Iceland, Ireland, Spain and the U.S.) also experienced the highest degree of financial turmoil during the crisis.[3]

[2] Bernanke (2010) plots the cumulative change in current account balances and house prices for advanced economies between 2001Q4 and 2006Q4. The August 2007 ECB Monthly Bulletin features a similar figure for the period 1997-2005. Figure 2 extends the sample to include emerging market economies such as China, which play a key role in financing the U.S. current account deficit.

[3] Similar dynamics for capital inflows and real estate prices occurred before the Asian crisis in the late 1990s (see Obstfeld and Rogoff, 2010, and the references therein).

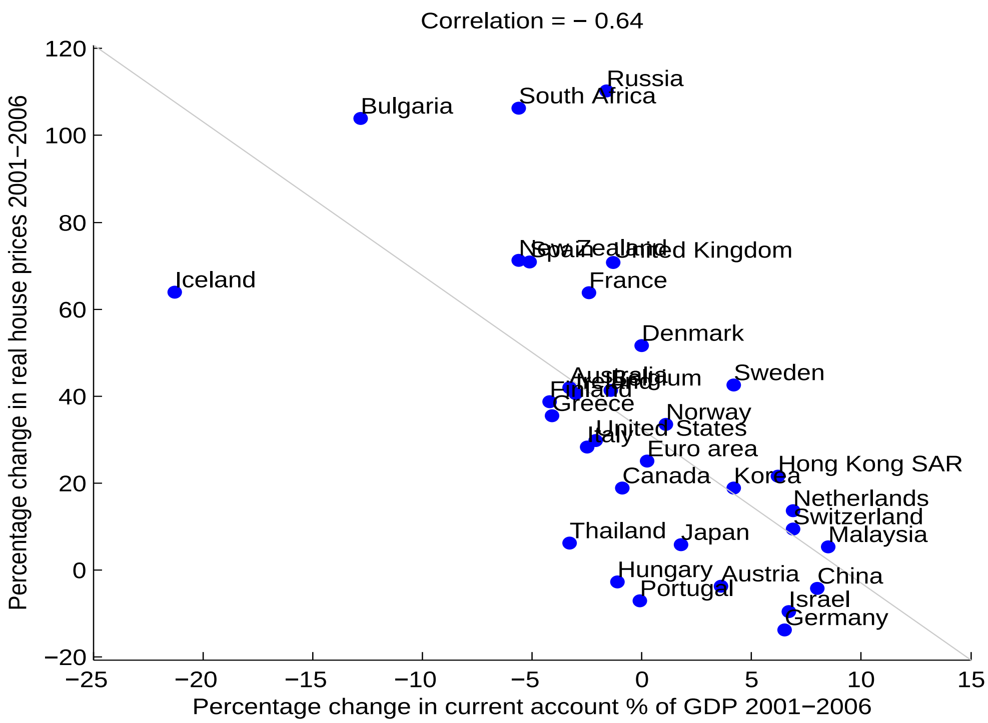

Figure 2: Percentage changes in current account % of GDP and in real house prices for advanced and emerging economies between 2001 and 2006. Source: Bank of International Settlements and author's calculations.

The most popular explanation for the negative correlation between current account balance and house prices is the so-called "global saving glut" hypothesis (Bernanke, 2005).[4] This paper takes a different perspective and shows that domestic factors, such as credit and preference shocks, can generate a strong negative correlation between house prices and the current account. This view is consistent with several pieces of both anecdotal and hard evidence on financial deregulation and a house price bubble, but raises an important issue. Domestic factors that give rise to an increase in house prices are akin to demand shocks, which put upward pressure on the equilibrium real interest rate. In contrast, the evidence shows that real interest rates sharply declined during the early 2000s (Figure 3).

This paper focuses on monetary policy in the U.S. and in the rest of the world to explain low interest rates. During the early 2000s, U.S. nominal interest rates were low for a "considerable period"—a language introduced for the first time in the August 2003 FOMC statement. If inflation expectations are stable, low nominal rates translate into low real rates. Additionally, after the Asian crises of the late 1990s, several emerging market (most notably China) and

[4]Caballero et al. (2008a) and Mendoza et al. (2009) formalize the idea of a global saving glut, with particular focus on the implications for the U.S. current account deficit.

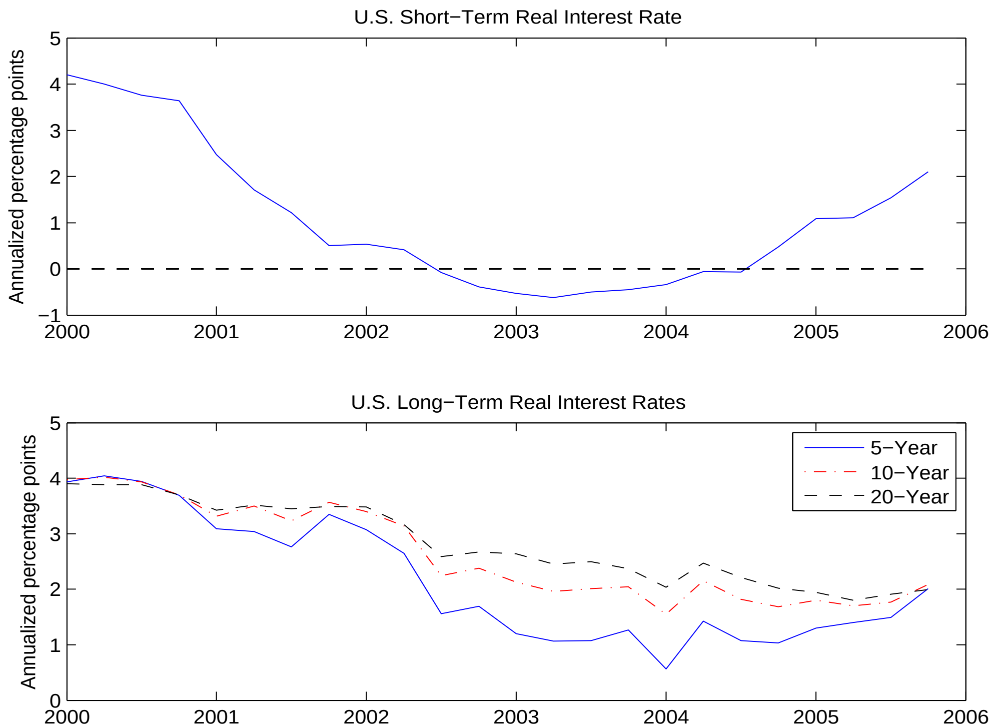

Figure 3: U.S. short-term (top panel) and long-term (bottom panel) real interest rates. The short-term rate is the nominal 1-year T-bill yield minus expected inflation from the Survey of Professional Forecasters. The long-term rate is the implied real rate from Treasury Inflation-Protected Securities (TIPS).

oil producing economies started pegging their nominal exchange rate to the U.S. dollar, thus "importing" U.S. monetary policy.[5] As a consequence, low U.S. interest rates propagate to the rest of the world, leading to low global interest rates. Foreign pegs exert additional downward pressure on the real interest rate and impair a depreciation of the dollar that would help rebalance the U.S. current account deficit.

Expansionary monetary policy in the U.S. and foreign exchange rate pegs in the rest of the world have the potential to play an important role for house prices and the current account. Indeed, according to Taylor (2008), loose U.S. monetary policy was the key determinant of house price appreciation, and the current account deficit was an immediate consequence. Developments in mortgage markets and the securitization process only contributed to worsen the problem.[6] From a qualitative perspective, monetary policy shocks and foreign pegs do

[5]Dooley et al. (2008) label the resulting international monetary regime "Bretton Woods II." Their work emphasizes the interplay between managed exchanged rate regimes in Asian countries and U.S. current account deficits. The basic idea is that emerging economies stimulate their exports (their main source of growth) by keeping the domestic currencies artificially undervalued relative to fundamentals.

[6]In a small open economy, Iacoviello and Minetti (2003) relate the strength of the impact of monetary policy

contribute to amplify the boom in house prices as well as to widen the current account deficit. However, their quantitative contribution is extremely small. The implication is that factors other than monetary policy were the key driver behind the housing boom and the deterioration of the current account. This conclusion is consistent with the arguments in Bernanke (2010) and the evidence in Favilukis et al. (2011).

The analysis relies on a calibrated two-country framework with tradable consumption goods and housing, whose purchases are subject to an endogenous borrowing constraint, as in Kiyotaki and Moore (1997). The model is deliberately simple and abstracts from a number of important factors—such as within-country borrowing and lending, heterogenous locations, and elastic housing supply—which have certainly played a role in the housing market during the years that preceded the recent crisis. The key objective is to use the model to generate a boom in house prices and evaluate its consequences for the current account and, most importantly, real interest rates.

An exogenous increase in the borrowing constraint parameter, for a given value of the collateral, leads households to lever up and demand more consumption of goods and housing services, hence driving up house prices and strengthening the effect of financial deregulation.[7] To the extent that the relaxation of credit constraints affects the whole economy, the increase in domestic borrowing must be financed from abroad, thus generating a current account deficit. Similarly, preference shocks for housing also deliver a negative correlation between house prices and the current account (Gete, 2009), although the consequences for foreign indebtedness are slightly smaller.[8] Monetary policy shocks are identified as departures of the measured Federal Funds Rate (FFR) from the interest rate implied by a standard feedback (Taylor) rule in the U.S. during the period 2000-2005. These shocks, in conjuction with foreign pegs, explain low real interest rates, but do not significantly alter the profile of house prices and the current account.

The rest of the paper proceeds as follows. Section 2 presents the model. Section 3 discusses the calibration. Section 4 introduces the baseline experiments, highlighting the implication for the real interest rate. Section 5 addresses the quantitative importance of overly-accommodative

shocks on house prices to the degree of financial liberalization.

[7]Midrigan and Philippon (2011) use credit constraint shocks in an island economy to match the distribution of house prices across U.S. counties. Eggertsson and Krugman (2012) and Guerrieri and Lorenzoni (2010) argue that a tightening of borrowing constraints (relative to pre-crisis levels) can lead to a substantial drop in aggregate demand and potentially create depression-like scenarios.

[8]Iacoviello and Neri (2010) estimate a closed economy DSGE model with housing and find that slow technological progress in the housing sector explains the long run upward trend in U.S. house prices. Housing preference and technology shocks account for about 50% of the variance of housing investment and prices at business cycle frequencies. In a two-country, two-type (borrowers and savers in each country) model with residential investment, Punzi (2006) shows that the impulse responses to shocks to preference for housing, technology in the housing sector and collateral constraints are broadly consistent with VAR evidence.

U.S. monetary policy and foreign exchange rate pegs. Finally, the last section concludes.

2 An Open Economy Model with Borrowing Constraints

Time is discrete and indexed by t. Two countries of equal size (Home and Foreign) form the world economy. In each country, a representative household consists of a continuum of measure one of workers, who share the consumption of a tradable composite of goods produced domestically and abroad, as well as housing services, which are assumed to be proportional to the fixed housing stock. An endogenous collateral constraint limits the maximum amount of private credit to a fraction of the expected value of housing. A representative retailer packages differentiated intermediate goods into the homogeneous final tradable good. A continuum of measure one of monopolistic competitive firms produce the intermediate goods, using labor as the only factor of production. A representative labor agency combines the differentiated labor inputs into the homogeneous aggregate. Goods and labor markets are imperfectly competitive. Prices and wages are set on a staggered basis. The law of one price holds but home bias in consumption implies that purchasing power parity is violated. International financial markets are incomplete. The only asset traded across countries is a one-period nominal risk-free bond denominated in the Home currency. All exogenous shocks considered below are specific to the Home country. The first is a preference shock for housing. The second is a change in the tightness of the borrowing constraint parameter. The third is a monetary policy innovation.

This section presents the household and firms' problems from the perspective of the Home country. An asterisk denotes foreign variables when relevant. Appendix A.1 reports the optimality conditions.

2.1 Household Preferences and Constraints

The representative household maximizes the expected discounted value of a utility function which depends positively on the consumption index X_t and negatively on hours worked by each member of the representative household $L_t(i)$

$$U_t \equiv \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \beta^s \left[\frac{X_{t+s}^{1-\sigma}}{1-\sigma} - \frac{1}{1+\nu} \int_0^1 L_{t+s}(i)^{1+\nu} di \right] \right\}, \tag{1}$$

where $\mathbb{E}_t$ is the expectation operator conditional on the information set available at time t, $\beta \in (0,1)$ is the discount factor, $\sigma > 0$ is the coefficient of relative risk aversion and $\nu > 0$ is the inverse Frisch elasticity of supply of a specific labor input.

The index X_t combines consumption of goods C_t and housing services H_t with constant elasticity of substitution $\epsilon > 0$

$$X_t \equiv \left[\omega C_t^{\frac{\epsilon-1}{\epsilon}} + (1-\omega)e^{\eta_t} H_t^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}}, \tag{2}$$

where $\omega \in (0,1)$ is the share of tradable goods in total consumption and η_t is a preference shock for housing that follows a first-order autoregressive process

$$\eta_t = \rho_\eta \eta_{t-1} + \varepsilon_{\eta t},$$

with $\rho_\eta \in (0,1)$ and $\varepsilon_{\eta t} \sim$ i.i.d. $\mathcal{N}(0, \sigma_\eta^2)$. As in Iacoviello and Neri (2010) and Justiniano et al. (2013), a positive preference shocks for housing takes the form of an increase in η_t.[9]

The tradable bundle C_t combines consumption of goods produced in the Home (C_{ht}) and Foreign (C_{ft}) country with constant elasticity of substitution $\gamma > 0$

$$C_t \equiv \left[\alpha^{\frac{1}{\gamma}} C_{ht}^{\frac{\gamma-1}{\gamma}} + (1-\alpha)^{\frac{1}{\gamma}} C_{ft}^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}, \tag{3}$$

where $\alpha \in [0.5, 1)$ is the share of domestic tradable goods.[10] Expenditure minimization implies that the consumption-based domestic price index is

$$P_t = \left[\alpha P_{ht}^{1-\gamma} + (1-\alpha) P_{ft}^{1-\gamma}\right]^{\frac{1}{1-\gamma}},$$

where P_{jt} is the price of good $j = \{h, f\}$ defined in Home currency. The law of one price holds for tradable goods (i.e. $P_{jt} = \mathcal{E}_t P_{jt}^*$, where $\mathcal{E}_t$ is the nominal exchange rate). However, because of home bias in preferences, purchasing power parity fails (i.e. $P_t \neq \mathcal{E}_t P_t^*$), and the real exchange rate ($S_t \equiv \mathcal{E}_t P_t^* / P_t$) is generally different from one.

The budget constraint for the representative household in nominal term is

$$P_{ht}C_{ht} + P_{ft}C_{ft} + \mathcal{Q}_t H_t - \mathcal{B}_t \leq \int_0^1 W_t(i) L_t(i) di + \mathcal{P}_t + \mathcal{Q}_t H_{t-1} + T_t - (1 + i_{t-1})\mathcal{B}_{t-1}, \tag{4}$$

where $\mathcal{Q}_t$ is the price of housing, $W_t(i)$ is the wage for the specific labor input supplied by

[9] Gete (2009) considers preference shocks for housing that induce time variation in ω. This alternative formulation has a direct impact on the Euler equation for consumption too, while η_t in this model only affects directly the house price equation.

[10] If $\alpha > 0.5$, preferences for tradable goods exhibit home bias. The Foreign tradable bundle places a weight α on consumption of Foreign tradable goods.

the i^{th} household member, $\mathcal{P}_t$ are profits from ownership of intermediate goods producers, T_t are lump-sum transfers and i_t is the net nominal interest rate on an internationally-traded one-period risk-free debt instrument $\mathcal{B}_t$, denominated in the Home currency.

Household members perfectly pool their idiosyncratic consumption risk, due to staggered price and wage setting, within each country. The representative household can smooth consumption intertemporally by borrowing and lending in international financial markets, subject to a collateral constraint that depends on the expected value of housing

$$(1 + i_t)\mathcal{B}_t \leq \Theta_t \mathbb{E}_t(\mathcal{Q}_{t+1} H_t), \tag{5}$$

where the borrowing constraint parameter $\Theta_t \in (0, 1)$ follows a first-order autoregressive process in log-deviations from steady state

$$\theta_t \equiv \ln(\Theta_t/\Theta) = \rho_\theta \theta_{t-1} + \varepsilon_{\theta t},$$

with $\rho_\theta \in (0, 1)$ and $\varepsilon_{\theta t} \sim$ i.i.d. $\mathcal{N}(0, \sigma_\theta^2)$. The idea behind this type of borrowing constraint is that the Foreign household can only recover a fraction Θ_t of the collateral in case of default, possibly due to various costs associated with the bankruptcy process.[11]

In the model, all borrowing occurs from abroad. In practice, of course, most households borrow from domestic financial institutions to finance their consumption and housing purchases, and part of these funds come from other domestic households. Yet, during the early 2000s, the increase in funds originating from abroad crucially contributed to the credit boom. The working hypothesis in this paper is that these capital flows are the result of increased demand in the U.S. induced by financial deregulation and preference for housing.[12]

[11] See, for instance, Kiyotaki and Moore (1997) and Iacoviello (2005). An alternative formulation (e.g. Kocherlakota, 2000) would feature the current value of housing on the right-hand side of the constraint and would represent a more direct mapping between the borrowing constraint parameter in the model and LTV ratios in practice. The next section discusses this mapping for calibration purposes. Quantitatively, the results are not sensitive to the two different specifications.

[12] As mentioned in the introduction, the global saving glut hypothesis suggests instead a foreign origin for the capital flows toward the United States. The recent work by Acharya and Schnabl (2010) and Bruno and Shin (2012) qualifies the saving glut narrative, adding a role for global banks. The two explanations are obviously not mutually exclusive.

2.2 Labor Agencies and Wage Setting

Perfectly competitive labor agencies hire differentiated labor inputs from household members and supply intermediate goods producers with the composite

$$L_t = \left[\int_0^1 L_t(i)^{\frac{\phi_w - 1}{\phi_w}} di \right]^{\frac{\phi_w}{\phi_w - 1}}, \tag{6}$$

where $\phi_w > 1$ is the elasticity of substitution among differentiated labor inputs. Profit maximization for labor agencies gives the demand for the i^{th} labor input

$$L_t(i) = \left[\frac{W_t(i)}{W_t} \right]^{-\phi_w} L_t, \tag{7}$$

where W_t is the aggregate wage index implied by the zero profit condition for labor agencies

$$W_t = \left[\int_0^1 W_t(i)^{1-\phi_w} di \right]^{\frac{1}{1-\phi_w}}.$$

Household members are monopolistic supplier of their labor inputs and set wages on a staggered basis. In each period, independently of previous adjustments, the probability of not being able to reset the wage is ζ_w. A household member who is able to reset the wage at time t solves

$$\max_{\tilde{W}_t(i)} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} (\beta \zeta_w)^s \left[\lambda_{t+s} \tilde{W}_t(i) L_{t+s}(i) - \frac{1}{1+\nu} L_{t+s}(i)^{1+\nu} \right] \right\},$$

subject to (7) conditional on no further wage changes, where λ_t is the marginal utility of consumption at time t. Appendix A.1 reports the details on the first order condition and derives the associated wage Phillips curve.

2.3 Firms and Production

Competitive retailers pack intermediate goods according to a constant returns technology with elasticity of substitution $\phi_p > 1$

$$Y_{ht} \equiv \left[\int_0^1 Y_t(h)^{\frac{\phi_p - 1}{\phi_p}} dh \right]^{\frac{\phi_p}{\phi_p - 1}}. \tag{8}$$

Profit maximization gives the demand for the h^{th} good

$$Y_t(h) = \left[\frac{P_t(h)}{P_{ht}}\right]^{-\phi_p} Y_{ht}, \tag{9}$$

where P_{ht} is the aggregate price index for goods produced in the Home country implied by the zero profit condition for final goods producers

$$P_{ht} = \left[\int_0^1 P_t(h)^{1-\phi_p} dh\right]^{\frac{1}{1-\phi_p}}.$$

All intermediate goods producing firms (indexed by h) have access to the same constant return technology which uses the labor aggregate L_t as the only factor of production

$$Y_t(h) = AL_t(h), \tag{10}$$

where A is a constant productivity factor. Intermediate goods producers set prices in domestic currency on a staggered basis, where ζ_p is the probability of not being able to adjust the price in the future, independently of previous adjustments. A firm that can reset its price at time t solves

$$\max_{\tilde{P}_t(h)} \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} (\beta\zeta_p)^s \lambda_{t+s} \left[\tilde{P}_t(h) Y_{t,t+s}(h) - W_{t+s} L_{t+s}(h)\right] \right\}$$

subject to the technology constraint (10) and to the demand for their product (9) conditional on no further price changes in the future, which the firm takes as given.[13] Appendix A.1 reports the details on the first order condition and derives the associated price Phillips curve.

Finally, the stock of housing (land) is assumed to be fixed

$$H_t = H. \tag{11}$$

This assumption gives the model the best chance to match the increase of house prices in response to domestic shocks. In practice, the housing boom was also accompanied by a large increase in residential investment.[14] However, interpreting housing as land fits well the evidence in Davis and Heathcote (2007), who find that land prices, rather than the price of structures,

[13] The representative household in each country owns the domestic firms. Therefore, the marginal utility of consumption, i.e. the Lagrange multiplier on the budget constraint, is the appropriate measure to convert the value of future profits in units of current consumption.

[14] In an estimated closed economy DSGE model with borrowers and savers, Iacoviello and Neri (2010) find that slow technological progress in the housing sector explains the long run upward trend in U.S. house prices, while housing technology shocks account for about 25% of the variance of house prices at business cycle frequencies.

explain the bulk of both trend growth and cyclical house price fluctuations between 1975 and 2006.

2.4 Monetary Policy

In models with housing, the price index P_t is typically not a sufficient statistic for inflation. The price index that central banks target in practice includes a significant weight on "owner-equivalent rent," that is, the rent that would be paid if a currently-owned property were to be rented. The idea is to include the cost of shelter in the index that measures the overall living costs. Although the model abstracts from a rental market, owner-equivalent rent (OER_t) can be defined as the price that an individual would pay to the owner to use the house for one period. In a competitive market, this price should equal the marginal rate of substitution between housing and consumption net of depreciation (Diaz and Luengo-Prado, 2008). Given the assumption of a fixed housing stock in this model, the resulting measure, excluding preference shocks, is

$$OER_t \equiv \frac{1-\omega}{\omega}\left(\frac{H}{C_t}\right)^{-\frac{1}{\epsilon}}.$$

The price index relevant for monetary policy decision is then assumed to be a weighted average of goods and owner-equivalent rent

$$P_{Xt} \equiv P_t^{\omega_X} OER_t^{1-\omega_X},$$

where $\omega_X \in (0,1)$ is the relative weight on goods prices. The central bank sets the short-term nominal interest rate in response to deviations of inflation and output from their targets

$$(1+i_t) = (1+i_{t-1})^{\rho_i}\left[(1+i)\left(\frac{\Pi_{Xt}}{\tilde{\Pi}_t}\right)^{\varphi_\pi}\left(\frac{Y_{ht}}{\tilde{Y}_{ht}}\right)^{\varphi_y}\right]^{1-\rho_i} e^{\varepsilon_{it}}, \tag{12}$$

where $\rho_i \in (0,1)$ is the degree of interest rate smoothing, $\Pi_{Xt} \equiv P_{Xt}/P_{Xt-1}$, $\varphi_\pi > 1$ and $\varphi_y > 0$ govern the intensity of the interest rate response to inflation and output, respectively, $\tilde{\Pi}_t$ and $\tilde{Y}_{ht}$ are the targets for inflation and output, respectively, and $\varepsilon_{it} \sim$ i.i.d. $\mathcal{N}(0,\sigma_i^2)$ is a monetary policy shock.

2.5 Equilibrium and Steady State

An imperfectly competitive equilibrium for the world economy is a sequence of prices and quantities such that:

1. The representative household in each country maximizes utility subject to the budget

constraint and the collateral constraint, taking prices as given. The household also sets wages on a staggered basis on behalf of its members to minimize the disutility of labor, taking demand for their specific labor input as given.

2. Intermediate goods producing firms set prices on a staggered basis to maximize the present discounted value of profits, taking the demand for their variety as given. Final goods producing firms minimize costs, taking prices as given.

3. The housing and labor markets clear in each country. Goods and financial markets clear internationally.

The full list of equilibrium conditions is in Appendix A.2. The quantitative experiments presented in this paper rely on a linearized version of the model around a deterministic steady state (see Appendix A.3 and A.4). In two-country open economy models, such a steady state is typically a symmetric equilibrium in which the net foreign asset position is zero. In the context of this model, zero foreign debt implies that the borrowing constraint in neither country can be binding in steady state (otherwise the borrowing constraint would pin down net foreign debt).

The unattractive feature of a symmetric steady state for current purposes is that, up to a linear approximation, borrowing constraints become irrelevant for house prices dynamics. A log-linear approximation of the equation for real house prices ($Q_t \equiv \mathcal{Q}_t/P_t$) yields

$$q_t = (1-\beta-\Xi\Theta)\left(\frac{1}{\epsilon}c_t+\eta_t\right)+\beta\left[\left(\frac{1}{\epsilon}-\sigma\right)(\mathbb{E}_t x_{t+1}-x_t)-\frac{1}{\epsilon}(\mathbb{E}_t c_{t+1}-c_t)\right]+\beta\mathbb{E}_t q_{t+1} \\ +\Xi\Theta\left[\xi_t+\theta_t+\mathbb{E}_t(\pi_{t+1}+q_{t+1})\right], \quad (13)$$

where lower case variables denote log-deviations from steady state and Ξ is the steady state value of the Lagrange multiplier on the borrowing constraint. The first line of the right-hand side of (13) is a standard user-cost equation for housing (durable goods), under the assumption of fixed supply. Real house prices are equal to the the current marginal utility of housing services in units of marginal utility of consumption plus the discounted expected value of future house prices. The second line measures the contribution of the shadow value of the borrowing constraint to current house prices. If the borrowing constraint were not to be binding in steady state, the multiplier would be equal to zero ($\Xi = 0$). Therefore, up to a first order approximation, changes in the borrowing constraint parameter θ_t would have no effects on real house prices.

The strategy to get around this issue adopted in this paper is to assume that the borrowing constraint always binds in the Home country because its representative household is relatively more impatient than the Foreign country's one ($\beta < \beta^*$).[15] In equilibrium, both in and outside the steady state, the Home country is a net borrower in international financial markets. Most importantly, this assumption rationalizes a role for shocks to the borrowing constraint in affecting house prices dynamics, at the cost of giving rise to an asymmetric steady state (characterized in Appendix A.3). The asymmetry, however, is small and limited to the steady state quantities. An appropriate normalization of the relative level of productivity and the housing stock makes relative prices equal across countries.[16]

3 Calibration

The Foreign discount factor pins down the steady state real return on the internationally traded asset. A target of 4% for the annualized real return implies $\beta^* = 0.99$. The Home country is a net borrower in international financial markets because of a lower discount factor ($\beta < \beta^*$). The next section discusses the exact value of this parameter in details.

The coefficient of risk aversion σ and the inverse Frisch elasticity of labor supply are both set equal to 2, within the range of common practice in macroeconomics (see, for instance, Hall, 2010). Also standard are the values for the elasticity of substitution among goods and labor varieties ($\phi_p = \phi_w = 7.67$), which are calibrated to match steady state a 15% markup in both the goods and labor market (Woodford, 2003). The price and wage stickiness parameters ($\zeta_p = \zeta_w = 0.75$) are chosen to match an average duration of price and wage contracts of four quarters (Nakamura and Steinsson, 2008).

The parameters of the goods consumption basket are fairly common in the international macroeconomics literature (see, for instance, Obstfeld and Rogoff, 2007). The domestic share of tradable consumption α, which governs the degree of home bias, is set to 0.7. The elasticity of substitution between Home and Foreign tradable goods γ equals 2.

The intratemporal elasticity of substitution between goods consumption and housing services ϵ is set equal to one. A Cobb-Douglas specification of the aggregator X_t is consistent with the micro evidence from the Decennial Census of Housing in Davis and Ortalo-Magné

[15]This assumption is quite common in models with borrowers and savers, such as Iacoviello (2005) or Monacelli (2009). Appendix A.4 reports the evolution of the Lagrange multiplier on the borrowing constraint across the different simulations and shows that, while getting very close to zero in one case, the multiplier does remain positive in all periods and experiments. Additionally, in practice, the available evidence suggests quite clearly that before the crisis the marginal borrower was always taking out the maximum possible loan, in spite of the progressive relaxation of borrowing constraints.

[16]Interestingly, the presence of a binding borrowing constraint also solves the problem of indeterminacy of the net foreign asset position typical of open economy models with incomplete international financial markets (Schmitt-Grohé and Uribe, 2003). The borrowing constraint at equality pins down the steady state level of net foreign assets as a function of house prices and the real interest rate.

(2011), indicating that expenditure shares on housing are constant over time and across U.S. metropolitan areas.[17] Conditional on the elasticity of substitution, the share of goods in the consumption aggregator ω is chosen to match a non-housing share of total expenditure of about 83%, which is in line with the average for the U.S. from 1929 to 2001 (Piazzesi et al., 2007).[18] The relative stock of housing is adjusted so that in steady state the level of house prices in the two countries is the same.

For simplicity, the steady state value of the terms of trade (and hence of the real exchange rate and the relative prices of Home and Foreign tradable goods) are normalized to one by appropriately picking the steady state productivity ratio A/A^*.

The targets and parameters of the monetary policy rule take fairly conventional values (e.g. Galí and Gertler, 2007). The inflation target is normalized to zero and the target for output is its steady state value. The interest rate smoothing parameter ρ_i is set equal to 0.7. As in Taylor (1993), the response to inflation ψ_π equals 1.5 while the response to output ψ_y equals 0.5. Finally, the weight ω_X on goods inflation in the price index P_{Xt} targeted by the central bank is set equal to 0.7, which implies a 30% weight on owner-equivalent rent ("Shelter" minus "Lodging away from home" and "Tenants' and household insurance") as in the U.S. Consumer Price Index (McCarthy and Peach, 2010).

4 Domestic Shocks and House Price Booms

This section considers two types of domestic shocks that can generate house price booms of the magnitude observed in the U.S. and in other advanced economies in the first half of the 2000s. The first shock is a relaxation of the collateral constraint parameter Θ_t. The second shock is an exogenous shift in the relative preference for housing η_t.

4.1 Relaxation of Borrowing Constraints

A relaxation of the borrowing constraint parameter Θ_t is meant to capture the effect of financial deregulation that started during the early 1980s on private borrowing (Campbell and Hercowitz, 2005). This process shifted into higher gear in the late 1990s and early 2000s, leading to an increase in household debt from 58% to 78% of GDP between the beginning of 2001 and the end of 2005 (Figure 4). The housing sector (mortgage debt and home equity loans) accounts for almost the whole increase.

[17]The Cobb-Douglas specification is the baseline case also in Fernandez-Villaverde and Kruger (2001), who study life-cycle consumption and portfolio decisions in a quantitative general equilibrium model with borrowing constraints.

[18]In order to match the same target, the value of ω^* is slightly higher for the Foreign country, where the borrowing constraint is slack.

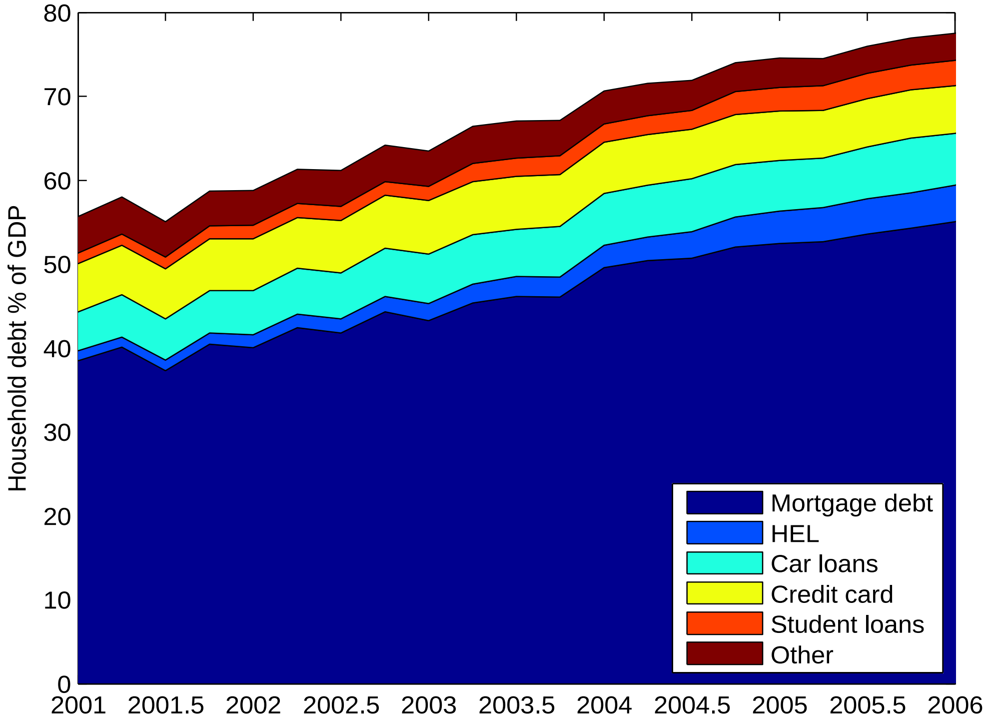

Figure 4: Composition of U.S. household debt % of GDP. Source: Federal Reserve Bank of New York Quarterly Report on Household Debt and Credit, Bureau of Economic Analysis and author's calculations. The FRBNY Quarterly Report on Household Debt and Credit is based on data from the New York Fed's Consumer Credit Panel—a nationally representative random sample drawn from Equifax credit reports. The data are available at http://data.newyorkfed.org/creditconditions/. See Lee and Van der Klaauw (2010) for a detailed overview.

While the rationale and the origins of the credit boom are certainly interesting per-se and well-worth investigating, the analysis below starts from the presumption that a relaxation of borrowing constraints occurred and studies the consequences on asset prices and macroeconomic quantities.[19] The relaxation of the borrowing constraint parameter is then a demand shock in the sense that lower values of Θ allow households to borrow more and hence increase their consumption of both goods and housing services.

Qualitatively, the intuition for why a relaxation of borrowing constraints generates a house price boom is simple. Suppose for a moment the Home country is a small open economy which takes the world gross interest rate R as given. Further, abstract from nominal rigidities and

[19] Rajan (2010) argues that easy credit in the U.S. was the consequence of the political response to increasing income inequality. Mian et al. (2013) show that, in the early 2000s, the mortgage industry started aggressively lobbying representatives from districts with a large fraction of subprime borrowers. Favara and Imbs (2010) trace instead the increase in supply of mortgage credit back to the deregulation of cross-state ownership of banks that started with the Interstate Banking and Branching Efficiency Act of 1994. Dynan et al. (2006) discuss other factors that may have contributed to explain the sharp rise in private credit.

assume the Home country receives a fixed endowment of a single consumption good Y. Finally, simplify preferences to be log-separable in consumption and housing. In a steady state with binding borrowing constraint, the real value of the housing stock in this economy is

$$QH = \frac{(1-\omega)C}{\omega(1-\beta-\Xi\Theta)}, \tag{14}$$

where $\Xi = (1-\beta R)/R$. The borrowing constraint at equality requires that debt is equal to a fraction of the discounted real value of the housing stock

$$B = \frac{\Theta QH}{R}. \tag{15}$$

Holding consumption constant, a permanent increase in the borrowing constraint parameter Θ permanently drives up the real value of the housing stock (equation 14). At the same time, the higher borrowing constraint parameter directly increases borrowing from abroad—an effect endogenously strengthened by the house price boom (equation 15). In the new steady state, the drop in consumption, necessary to pay back the higher foreign debt by running trade surpluses, partly mitigates the gains in house prices ($C = Y - (R-1)B$). Along the transition, however, consumption is temporarily higher because the increase in debt allows agents to spend more resources both on housing and goods consumption. The mitigating effect of intertemporal solvency on foreign liabilities kicks in only at a later stage.[20]

The quantitative relevance of the relaxation of borrowing constraints for the dynamics of house prices and the other macroeconomic variables crucially depends on the calibration of the stochastic process for θ_t and on the value of β. To give the financial deregulation experiment a chance to explain the profile of house prices in the data, the model is fed with a series of innovations $\varepsilon_{\theta t}$ between 2001 and 2005. The degree of persistence of the borrowing constraint parameter plays an important role in shaping agents' expectations about these innovations. A high degree of persistence ($\rho_\theta = 0.99$) is consistent with the "regime-switch" effect emphasized in Boz and Mendoza (2010). Agents in the model perceive the financial deregulation process essentially as permanent (i.e. a switch to a new regime), at least in the short run.

Obviously, the extent of the deregulation is also central for the results. Under a narrow interpretation, the parameter Θ represents the loan-to-value (LTV) ratio. Yet, a time series for this variable is not readily available. Duca et al. (2011) calculate median and trimmed mean (excluding top and bottom 10%) LTVs for first-time homebuyers from the American Housing

[20]Simulations of a permanent increase of the collateral constraint in this simplified version of the model suggest that the long-term negative effect on consumption is small relative to the early boom, so that the direct impact of financial deregulation on house prices dominates the long-run adjustment due to debt accumulation. See also Boz and Mendoza (2010) who study the amplification effect of learning following a financial deregulation experiment in a small open economy environment.

Survey between 1979 and 2011, both on all loans and excluding government loans. While LTVs so computed are noisy, as the number of first-time homebuyers in any given quarter can be small, both series display a clear upward trend during the period 1995-2005, with most of the increase taking place after 2000. Median private LTVs increase from about 85% in 1990 to almost 100% in 2008. The rise in the trimmed mean is slightly less extreme, reaching 95% by 2005.

This view of borrowing constraints is, however, quite restrictive. First, in the context of the model, the variable $\mathcal{B}$ does not strictly represent a mortgage contract but any form of collateralized borrowing that households can obtain against the value of housing. In particular, Mian and Sufi (2011) document that home equity loans by existing homeowners are responsible for a significant fraction of the increase in U.S. household leverage between 2002 and 2006. According to their estimates, the average homeowner extracted 25 cents per dollar of house price appreciation. Furthermore, the households in their sample did not appear to use the borrowed funds to buy new real estate or repay (high interest) credit card debt but rather for real outlays (consumption and home improvement). Second, the model has a stationary population of households who continuously refinance their loans. In practice, however, high LTVs allowed many new borrowers who previously could not afford a loan to become homeowners (Geanakoplos, 2010b,a). By the end of 2005, the marginal borrowers were mostly in the subprime segment and were often able to obtain a mortgage with zero down-payments.[21] Finally, while the relaxation of borrowing constraints in the model is the only dimension of financial deregulation, the actual process affected several aspects of credit availability, such as reduced transaction costs (Favilukis et al., 2011).

Based on this discussion, Figure 5 shows the results of two financial deregulation experiments. The first (continuous blue line) corresponds to a conservative reading of the evidence in Duca et al. (2011). The borrowing constraint parameter gradually increases from 85% to 95% between 2001 and 2006, as in Justiniano et al. (2013). In the second experiment (dashed red line), the increase is more extreme, from 75% to 99%, as in (Favilukis et al., 2011).[22] For low enough values of the domestic discount factor, the financial deregulation experiment generates the full increase in house prices (about 30%) observed in the U.S. between 2001 and 2006. In the more extreme scenario ($\Theta = 0.75$), the discount factor necessary to match the house price increase in the data ($\beta = 0.96$) is in line with values previously used in models with borrowers

[21] In the last years of the boom, Haughwout et al. (2011) document that the median LTV ratios on securitized non-prime mortgages from First American CoreLogic Loan Performance data increased from 95% in 2004 to 99% in 2006 and was equal to 100% for the 75^{th} percentile throughout this period.

[22] To obtain a profile of house prices that resembles the data, the borrowing constraint parameter remains at its peak value for one year (2006) and returns toward its initial steady state over the next five years (2007-2011). The results for the boom period are not particularly sensitive to these assumptions.

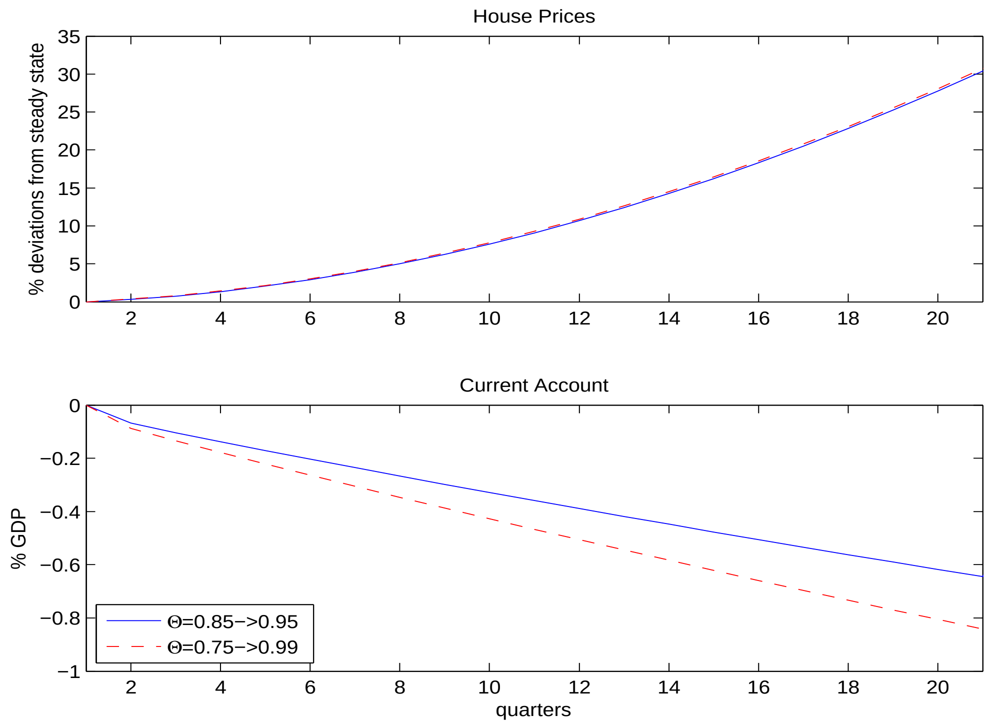

Figure 5: Simulated path of real house prices (top) and current account in % of GDP (bottom) in response to an increase in the borrowing constraint parameter Θ from 85% to 95% (continuous blue line) and from 75% to 99% (dashed red line) over five years.

and savers (e.g. Iacoviello, 2005). In the more moderate scenario ($\Theta = 0.85$), the value needs to be slightly lower ($\beta = 0.89$).[23]

A higher value of Θ allows the Home country to borrow more for a given value of the collateral and to increase the demand for consumption of both goods and housing. Because the stock of housing is fixed, house prices absorb the adjustment in full (top panel of Figure 5), providing an endogenous component to the relaxation of borrowing constraints. Also by construction, borrowing occurs in international financial markets only. Therefore, foreign debt increases and the current account turns negative (bottom panel of Figure 5).

The difference between the two cases is that, in the more moderate experiment (Θ from 85% to 95%), the increase in debt allowed by the relaxation of the borrowing constraint is smaller. Consequently, the deterioration of the current account is less pronounced, although the differences are not dramatic. The two simulations account between one-third and two-fifth of the deterioration of the U.S. current account as a percent of GDP between 2001q1 and 2005q4. Perhaps not surprisingly, the correlation between house prices and the current

[23] Across the two scenarios, the steady state value of ω is adjusted so that the consumption share of total expenditure remains equal to 83%. The rest of the steady state is unchanged.

account balance is almost perfectly negative (-0.97).

4.2 Preference Shocks: An Equivalence Result

The evidence on the relaxation of credit constraints in collateralized borrowing, though not systematic, is quite pervasive. For example, Abraham et al. (2008) document the increase in subprime lending as percentage of new mortgage origination after 2001 and note that Alt-A and subprime mortgages typically had much higher cumulative LTVs.

Using data from DataQuick that covers 89 metro areas in the United States, Glaeser et al. (2010) also find that the median combined LTV ratio on all housing purchases rose from 80% in 2004 to 90% in 2006. Moreover, extreme leverage, in the form of 100% LTV, was available and used by at least 10% of borrowers. This fraction became at least 25% in 2006. Yet, in their regressions, the magnitude of the LTV changes is not large enough to account for a significant fraction of the increase in house prices in a standard user cost model. Their conclusion is consistent with the analysis in Iacoviello and Neri (2010) and Justiniano et al. (2013), who attribute the bulk of the increase in house prices to preference shocks for housing—possibly a stand-in for a "bubble" component independent of fundamentals. While both these papers work in a closed economy environment, Gete (2009) shows that preference shocks can explain house price booms also in an open economy setting, leading to a negative correlation with the current account.

Motivated by this evidence, based on a different kind of domestic shocks, Figure 6 compares the moderate financial deregulation experiment in the previous section (continuous blue line) with a simulation driven by preference shocks for housing (dashed red line). This alternative simulations is constructed feeding the model with a sequence of unexpected negative innovations to η_t, engineered to explain the full increase in house prices over a five-year horizon (the persistence of the preference shock ρ_η is set to 0.99). The result is very much comparable to the financial deregulation experiment. While the deterioration of the current account is now slightly smaller, the correlation between house prices and the current account is again -0.97.

The equivalence result for house prices is perhaps not too surprising. The log-linearized house price equation (4.2) shows that the direct impact of a relaxation of borrowing constraint (an increase in θ_t) is just a scaled version of the direct impact of a preference shock for housing (an increase in η_t)

$$q_t = (1 - \beta - \Xi\Theta)\, \eta_t + \Xi\Theta\theta_t + ev_t,$$

where ev_t stands for "endogenous variables". The main difference is that preference shocks do not affect debt directly, as financial deregulation does. As a consequence, the deterioration in foreign indebtedness is less pronounced. Yet, the amplification channel of the borrowing

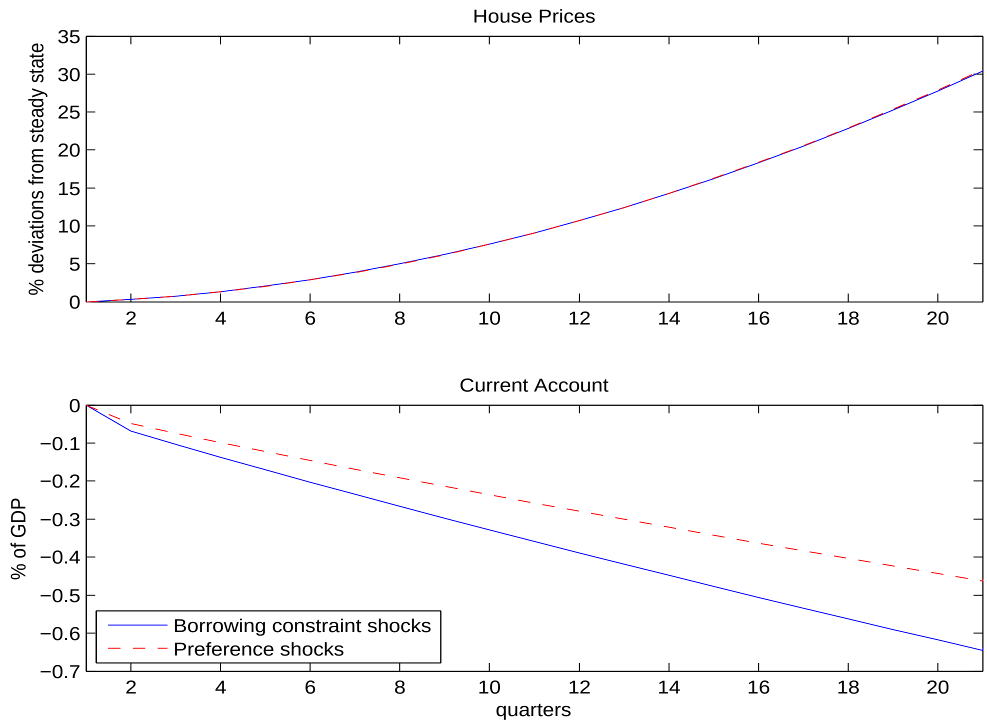

Figure 6: Simulated path of real house prices (top) and current account in % of GDP (bottom) in response to an increase in the borrowing constraint parameter Θ from 85% to 95% (continuous blue line) and to a sequence of preference shocks (dashed red line) over five years.

constraint through house prices works similarly as in the previous case.

4.3 A Real Interest Rate Puzzle

Domestic shocks that generate the full house price boom observed in the data lead to a deterioration of the current account as a fraction of GDP that accounts for 25 to 40% of its empirical counterpart during the 2000-2005 period. As in the data, the correlation between house prices and current account is almost perfectly negative.

In spite of this success, the simulations based on domestic shocks in the previous section share one main counterfactual feature. In the model, the real interest rate follows an hump-shaped pattern (bottom panel of Figure 7). Moreover, the magnitude of the real interest rate movements are quite small (half percentage point peak to trough). Conversely, in the data, the U.S. short-term real interest rate substantially declined in the early 2000s, and started to increase only in late 2004 (top panel of Figure 7).[24]

[24]Long-term real interest rates derived from U.S. Treasury Inflation Protected Securities (TIPS) behaved similarly during this period. Part of the decline in real interest rates may be due to forces operating at very low frequencies,

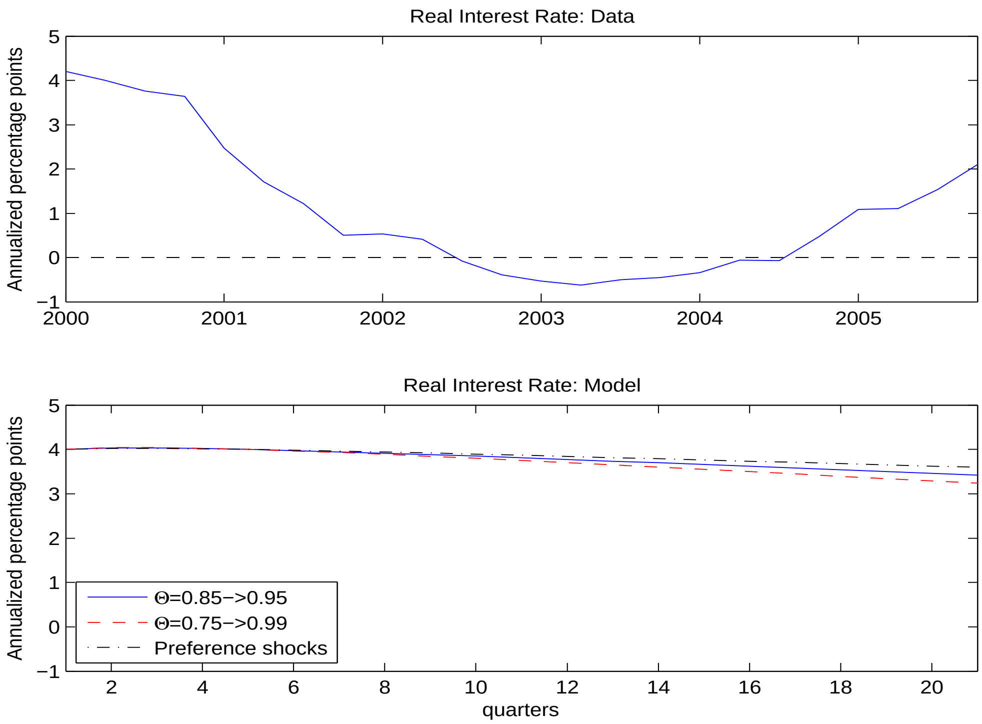

Figure 7: Top panel: Real interest rate in the data calculated as the nominal yield on a 1-year T-bill minus expected inflation from the Survey of Professional Forecasters. Bottom panel: Real interest rate in the model under different scenarios for the house price boom (moderate financial deregulation: continuous blue line; extreme financial deregulation: dashed red line; preference shocks: dashed-dotted black line).

Less stringent lending standards, as well as preference shocks for housing, stimulate aggregate demand in the Home country while the current account turns negative. The Home country central bank responds to this type of shocks hiking the nominal interest rate, which accounts for the initial rise of the real interest rate. As the current account deficit grows larger, however, the nominal exchange rate starts depreciating to compensate for the external imbalances increases (Obstfeld and Rogoff, 2007), feeding into expectations of higher future inflation. This second part of the adjustment explains the later decline of the real interest rate via the Fisher parity. The overall effect is stronger in the case of more extreme financial deregulation and less so in the case of preference shocks, because, as mentioned, the two experiments have different implications for foreign debt. But the magnitudes are fairly comparable across scenarios. The model, therefore, misses one important dimension of the global macroeconomic scenario of the first half of the 2000s.

Most of the recent literature has interpreted the persistent drop in the real interest rate

such as demographic trends (Ferrero, 2010; Favero et al., 2011).

as a consequence of a "saving glut" originated outside of the U.S. (Bernanke, 2005).[25] In particular, Caballero et al. (2008b) explicitly link the capital flows associated with the saving glut hypothesis to the boom of housing and commodity prices. Even papers that attribute the house price boom to the financial deregulation process, such as Boz and Mendoza (2010) and Favilukis et al. (2011), have nevertheless relied, at least to some extent, on the saving glut hypothesis. The next section explores a different (and potentially complementary) rationale for low real interests at the world level, related to U.S. and global monetary policy.

5 The Role of Monetary Policy

Domestic shocks can account for the strong negative correlation between house prices and the current account in the U.S. during the first half of the 2000s. However, this explanation implies a counterfactual path for the real interest rate. The global saving glut hypothesis, either in isolation or in conjunction with other stories, provides one rationale for the low real interest rates observed in the data. This section investigates the role of monetary policy as an alternative mechanism that keeps world real rates low.

The basic idea is that, if inflation expectations remain well-anchored, a central bank that sets the nominal interest rate essentially controls the real rate. Some observers (most notably Taylor, 2008) have argued that the Federal Reserve, as well as central banks in other countries, kept nominal interest rates artificially low for too long after the 2001 recession. According to this interpretation, expansionary monetary policy shocks may have contributed to stimulate demand beyond what would be normally considered appropriate according to the predictions of a standard interest rate rule (e.g. Taylor, 1993). Therefore, monetary policy may be responsible not only for low interest rates but also for generating the boom in house prices and contributing to the deterioration of the current account.

While the role of the dollar as a reserve currency may justify the prominent role of U.S. monetary policy in influencing the world real interest rate, overly accommodative U.S. monetary policy alone may not be enough to keep the world real interest rate low for a prolonged period. One notable feature of the late 1990s and early 2000s period is that several emerging market economies—the main counterparties financing the U.S. current account deficit—were pegging their nominal exchange rate to the dollar, thus effectively importing U.S. monetary policy. In this environment, low U.S. interest rates spread globally as pegging countries lose

[25] In Caballero et al. (2008a) and Mendoza et al. (2009), financial frictions in emerging economies (either a shortage of collateral or a higher degree of market incompleteness, respectively) lead to capital flows toward the United States. Shin (2012) and Acharya and Schnabl (2010) argue that these flows were instead primarily driven by European banks. In both stories, a higher demand for (perceived) safe assets is at the heart of the mechanism.

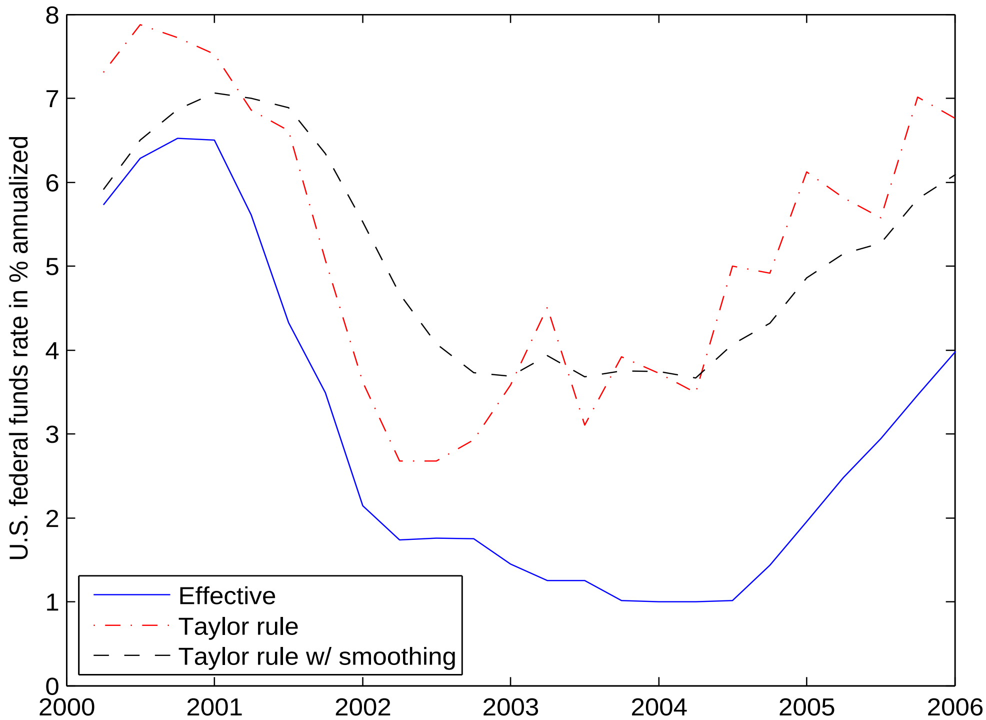

Figure 8: Effective federal funds rate (continuous blue line) and nominal interest rate predicted by a Taylor rule with (dashed black line) and without (dashed-dotted red line) smoothing. Source: DLX/Haver and author's calculations.

their control on domestic interest rates.[26] The question then becomes whether foreign exchange rate pegs have exacerbated the magnitude of the adjustment due to U.S. regulatory and monetary policy factors.

The next two sections formalize these ideas in the context of the model.

5.1 Over-Expansionary U.S. Monetary Policy

Figure 8 compares the effective Federal Funds Rate (FFR) in blue with the nominal interest rate predicted by a standard interest rate rule (Taylor, 1993), similar to the linearized version of equation (12) in the model

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)(\psi_\pi \pi_t + \psi_y y_{ht}) + \varepsilon_{it}, \tag{16}$$

where i_t is the effective FFR, π_t is the year-over-year CPI inflation rate and y_t is the deviation of real GDP from potential output as measured by the Congressional Budget Office. The

[26]Countries can retain some control on domestic monetary policy while pegging their exchange rate by imposing restrictions on foreign capital flows, as in the case of China.

difference between the dashed-dotted red line and the dashed black line is the value of the smoothing parameter ρ_i, which is set equal to zero in the first case and to 0.7 as in the baseline calibration in the second case.

Figure 8 captures the essence of the criticism in Taylor (2008). Between 2001 and 2005, U.S. monetary policy was excessively accommodative compared to the prescriptions of an interest rate rule that characterized well monetary policy in the previous two decades. According to this view, lower interest rates facilitated borrowing and led to higher house prices. Easy monetary policy is then a primary culprit for the house price boom.

The U.S. is not the only country with significant deviations from a standard monetary policy rule. Taylor (2008) presents evidence on the correlation between housing investment and deviations from a Taylor rule among European countries.[27] Countries that have experienced the largest deviations have also experienced the most significant changes in housing investment as percentage of GDP. These countries are also the very same with a high correlation between house price and current account changes during the period 2001-2006.[28]

In Figure 9, domestic shocks generate the house price boom. In this simulation (dashed red line), the model is fed with a combination of borrowing constraint and preference shocks. The financial deregulation component corresponds to the moderate scenario of the previous section (an increase in the borrowing constraint parameter Θ from 85% to 95%). The discount factor for the Home representative household β is set to 0.95, as in Iacoviello (2005). The relaxation of the borrowing constraint accounts for slightly more than 50% of the total increase in house prices. Preference shocks for housing explain the remaining portion of the increase. The continuous blue line in Figure 9 adds to these two shocks a sequence of monetary policy innovations, calculated as departures of the effective FFR from the prescriptions of (16). For consistency between model and data, the series of monetary policy shocks is calculated using (16) with $\rho_i = 0.7$. Interest rate rules that feature a smoothing term generally provide a better fit of the data (Clarida et al., 2000). Furthermore, the presence of the smoothing term introduces some forecastability of previous monetary policy shocks, hence partly capturing the Federal Reserve's communication strategy during the 2003-2004 period.

The top and center panels of Figure 9 highlight how little monetary policy shocks contribute to house price appreciation and the deterioration of the current account. Borrowing constraint

[27]Deviations from the Taylor rule differ among Euro countries because inflation and output gaps are country-specific.

[28]One limitation of this argument is that the correlation between the departures from a standard Taylor rule and house price appreciation in the cross section is much weaker than for residential investment (Bernanke, 2010). While this evidence may question the importance of easy monetary policy in causing the housing boom, low interest rates may still play an important role as an amplification mechanism (Adam et al., 2011). Furthermore, combining other domestic shocks with an easy monetary policy stance allows for a quantitative evaluation of the relative importance of these alternative explanations for the boom in house prices and the deficit on the current account.

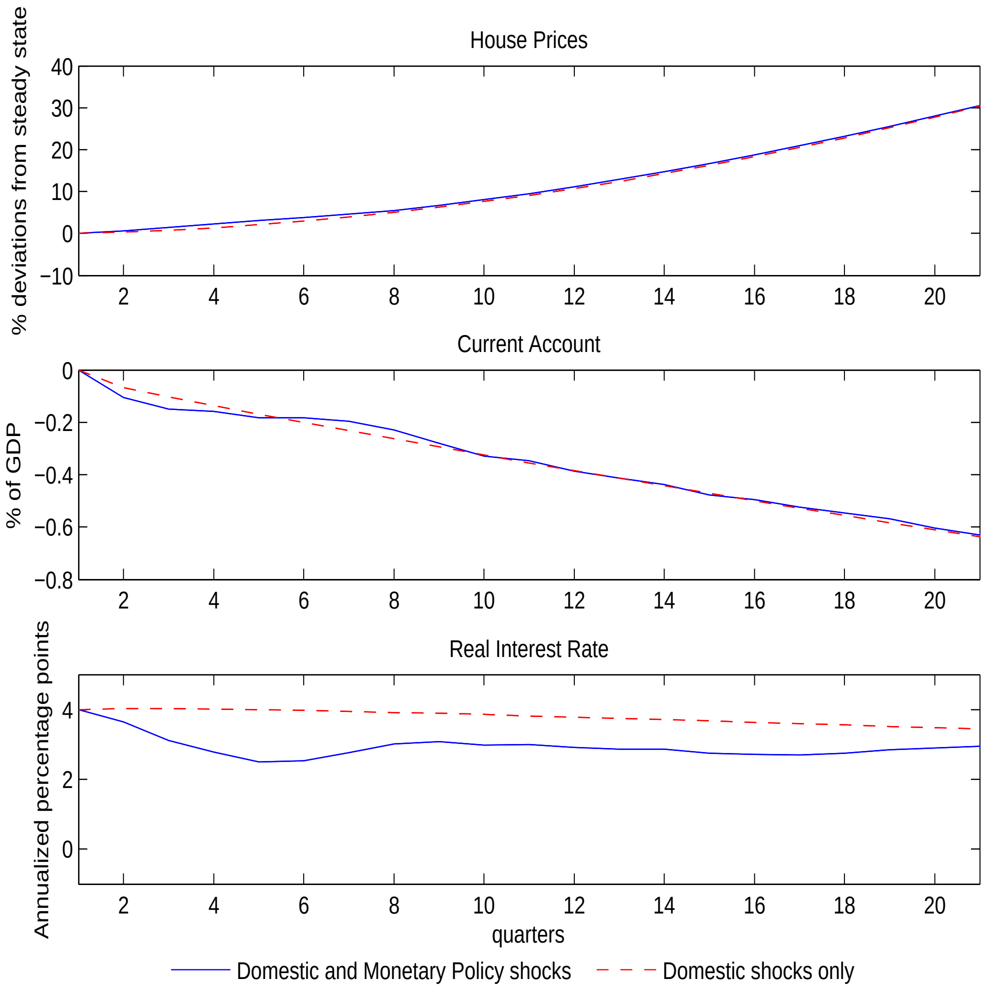

Figure 9: Simulated path of real house prices (top), current account in % of GDP (center), and real interest rate (bottom) in response to domestic and monetary policy shocks (continuous blue line) and domestic shocks only (dashed red line).

and preference shocks remain pretty much the unique driving force for these two variables. If monetary policy shocks were the only source of variation, house prices and the current account would barely move.

Monetary policy shocks, however, play a key role for the dynamics of the real interest rate (bottom). Because the systematic part of the monetary policy rule is unchanged, inflation expectations remain anchored, and low nominal rates translate into low real rates (bottom-left panel). The fall in real rates is still less than in the data, but the magnitude is significant—about 1% on average over the five-year simulation horizon—and the difference with the case of credit and preference shocks only is quite notable. Low real rates also contribute to stimulate consumption. Absent monetary policy shocks, consumption is essentially flat, as the endogenous initial increase in nominal rates counteracts the stimulus associated with the collateral

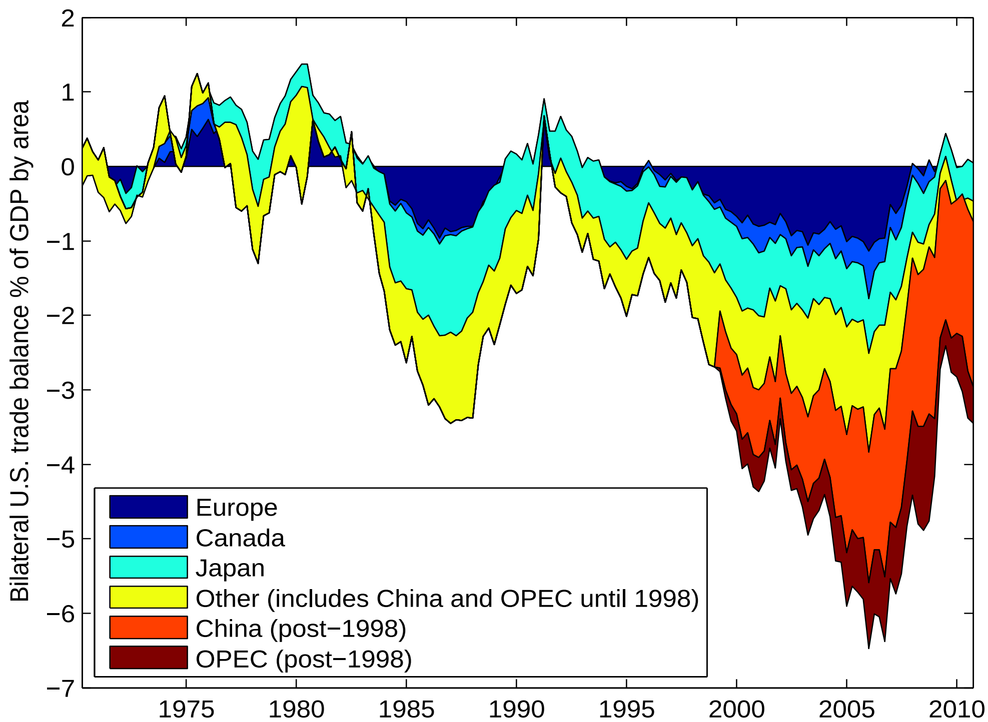

Figure 10: Bilateral U.S. trade balance % of GDP by area. Source: Bureau of Economic Analysis and author's calculations.

channel. Conversely, the monetary expansion generates an average 3% consumption boom over the simulation horizon, comparable to the 2% average deviation of non-durable consumption relative to trend over the period 2001-2005.

The introduction of monetary policy shocks improves the empirical performance of the model in terms of the real interest rate and consumption, leaving unchanged the fit of house price dynamics and the negative correlation with the current account balance. The fall in the real interest rate, however, is still less pronounced than in the data. While other non-monetary factors, such as saving glut shocks, may account for the missing portion, the next section explores the role of the Foreign exchange rate regime in amplifying domestic monetary policy shocks.

5.2 Foreign Exchange Rate Pegs

One important feature of the international monetary system since the late 1990s is the fact that many emerging economies, mostly in East Asia (and most notably China) and among oil producers, have pegged their exchange rate to the U.S. dollar.[29]

Dooley et al. (2008) have called this extensive peg arrangement "Bretton Woods II." In their view, pegged exchange rates among fast-growing, export-oriented economies are responsible for the large external imbalances between the U.S. and the rest of the world. Indeed, these countries have played a major role in financing the U.S. external imbalances in recent years (Figure 10).

The intuition is that pegged exchange rates keep foreign currencies significantly below their true market value, hence stimulating exports and growth abroad. From the perspective of the emerging economies, the peg may have been a reasonable policy. The consequence for the U.S., however, has been a series of widening current account deficits. For the purpose of this paper, the key question is how much foreign exchange rate pegs have contributed to exacerbate the boom in house prices.

Figure 11 compares the simulation in the previous section (continuous blue line) with the case in which the monetary authority of country F follows an exchange rate peg (dashed red line)

$$\mathcal{E}_t = \bar{\mathcal{E}}.$$

The fixed exchange rate arrangement in the rest of the world does not significantly change the dynamics of house prices and the current account. House prices are on average 3.3 percentage points higher (4 percentage point differential at the peak). The peg magnifies the current account deficit during the first year of the simulation, but the effect is relatively small (less than 0.2 percentage points at the peak). Conversely, the real interest rate drops more than five times as much than in the flexible exchange rate regime.

Inspecting the Fisher parity condition ($r_t = i_t - \mathbb{E}_t \pi_{t+1}$) suggests that both the fall in the nominal interest rate and the increase in expected inflation are larger under the peg than in the case of flexible exchange rates, although quantitatively the first component dominates. In a floating environment, as monetary policy becomes more expansionary, not only domestic demand rises, but also the nominal exchange rate tends to depreciate, making Home goods more attractive for foreigners. Higher foreign demand stimulates domestic production and leads to an increase in domestic prices. As a consequence, the endogenous component of the interest rate rule partly compensates for the exogenous expansionary shocks. This mechanism is absent under a peg. In this case, the increase in prices occurs also abroad. The Home country exports the main consequences of its expansionary monetary policy—a feature also discussed by Ferrero et al. (2010) in the context of the current account rebalancing scenarios under fixed exchange rates involving the U.S. and China. Additionally, lower nominal interest

[29] See the International Monetary Fund exchange rate regime classification, summarized for the period 1970-2007 in Reinhart and Rogoff (2009).

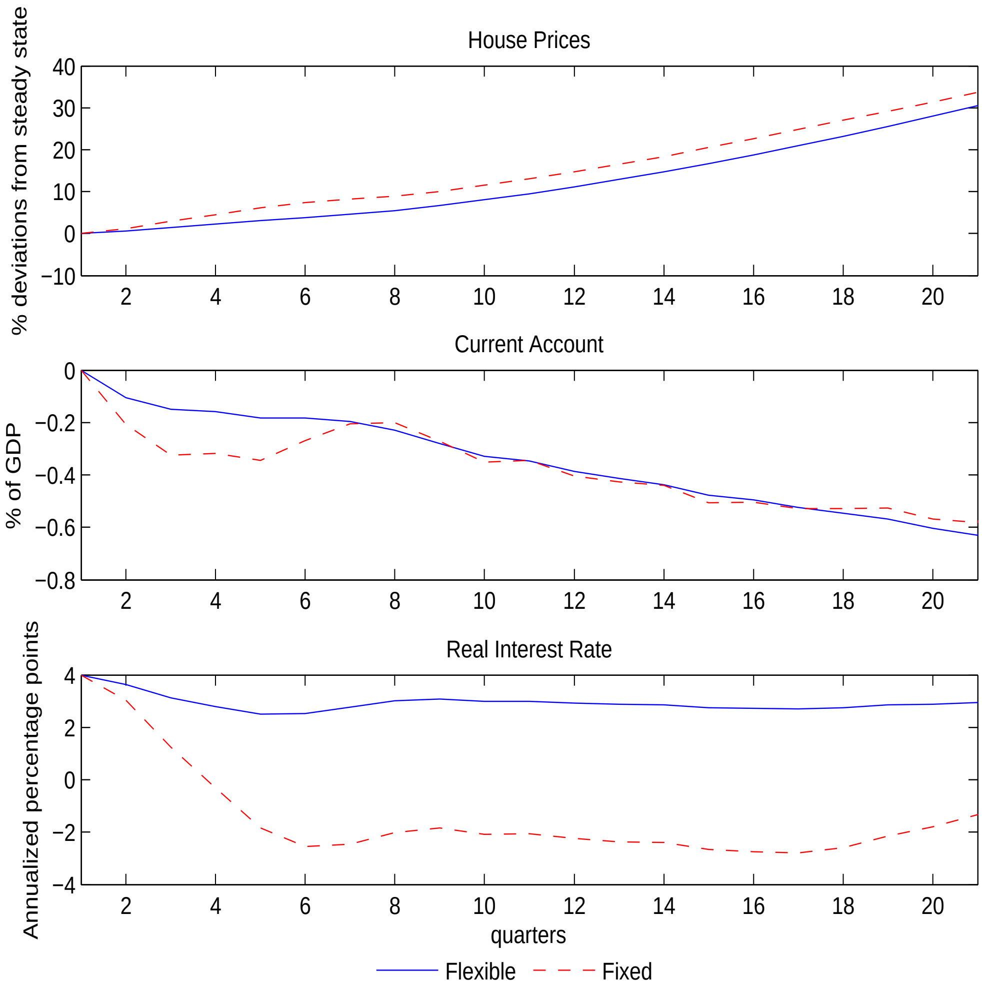

Figure 11: Simulated path of real house prices (top), current account in % of GDP (center), and real interest rate (bottom) in response to domestic and monetary policy shocks under a flexible (continuous blue line) and fixed (dashed red line) exchange rate regime in the Foreign country.

rates at Home imply higher expected domestic inflation (in spite of the absence of a nominal depreciation), which further reduces the real interest rate.

A pure peg in the rest of the world may be an extreme characterization of the true international system of exchange rates. Indeed, under a pure peg, the real interest rate falls even more than in the data. A perhaps more realistic approach would be to assume that the Foreign country Taylor rule places a positive (and non-negligible) weight on the depreciation of the nominal exchange rate

$$i_t^* = \rho_i i_{t-1}^* + (1-\rho_i)(\psi_\pi \pi_t^* + \psi_y y_{ft}) - \psi_e \Delta e_t + \varepsilon_{it}^*,$$

with $\psi_e > 0$. In this case, not surprisingly, an intermediate adjustment would obtain. For example, if $\psi_e = 1.5$, the adjustment of house prices and the current account essentially coincides with the flexible exchange rate scenario, while the drop in the real interest rate essentially coincides with the fall in the data.

All in all, assuming the Foreign country pegs its nominal exchange rate to the Home currency (whether fully or partially) helps the model align better with the data in terms of the behavior of the real interest rate, without substantially affecting the dynamics of house prices and the current account.

5.3 Monetary Policy and House Price Booms

Most of the analysis so far has focused on the correlation between house prices and the current account, and on the dynamics of the real interest rate. Because monetary factors (shocks to the nominal interest rate and the exchange rate regime) play a central role for the results, this section discusses two critical assumptions of the model. The first is that the paper treats financial innovation as exogenous to monetary policy (shocks). The second aspect concerns the possibility that the central bank may respond to house price appreciation above and beyond the weight implied by the definition of Π_{Xt}.

5.3.1 Financial Innovation and Monetary Policy

The results so far clearly suggest a dichotomy in accounting for the main observable variables object of this study. While credit and preference shocks explain the house price boom and the current account deficit, monetary policy is responsible for low interest rates. In the model, the two driving forces are orthogonal to each other. In practice, low interest rates may have encouraged excessive risk-taking by financial institutions, hence leading to an endogenous relaxation of credit standards (Rajan, 2010). Some recent empirical evidence supports this hypothesis (e.g. Maddaloni and Peydró, 2011), consistent with the theory in Diamond and Rajan (2000, 2001).[30]

In order to address whether the financial deregulation exercise conducted in the previous section misses a significant link with monetary policy, loan-to-value ratios are regressed on both the level of the effective Federal Funds Rate and its deviations from the predictions of

[30] In Angeloni and Faia (2013), the risk-channel of monetary policy coexists with the standard argument for price stability arising from nominal rigidities. Cociuba et al. (2012) highlight one caveat to the identification of the risk-taking channel of monetary policy. In their work, low interest rates induce more risk-taking only in the presence of significant mis-pricing of risky assets, thus breaking the direct link with monetary policy. In fact, if risky assets are correctly priced, low interest rates actually decrease risk-taking by financial institutions.

Regression:	$LTV_t = \alpha + \rho LTV_{t-1} + \beta x_t + u_t$			
	$x_t = \varepsilon_{FFR,t}$		$x_t = FFR_t$	
	(1)	(2)	(3)	(4)
α	-0.010	-0.004	-0.001	0.000
	(-1.981)	(-0.837)	(-0.262)	(0.040)
ρ		0.641		0.640
		(8.163)		(8.196)
β	-0.013	-0.005	-0.008	-0.003
	(-4.018)	(-1.915)	(-4.033)	(-2.025)
R^2	0.145	0.500	0.146	0.502
Observations	96	96	96	96

Table 1: Coefficient estimates of a regression of loan-to-value ratios (LTV_t) on the level of the effective Federal Funds Rate (FFR_t) or deviations of the effective Federal Funds Rate from the predicted Federal Funds Rate using the Taylor rule (16) ($\varepsilon_{FFR,t}$). Columns (2) and (4) include the lagged LTV as dependent variable. t-statistics are in parenthesis.

the Taylor rule in (16). Table 1 presents the results. The dependent variable is the median LTV for non-government first-time buyers from Duca et al. (2011).

The data is at quarterly frequency, covers the post-Greenspan era (1987q3-2011q3), and is expressed in annualized percentage points. Both the level and the innovations of the Federal Funds Rate yield statistically significant but economically negligible effects. A 1% decrease in either the FFR or in its departure from the prediction of a Taylor rule causes at most a 0.013% increase in LTVs. While other dimensions of risk-taking may be important (overall riskiness of the loan portfolio, funding structure, etc.), the direct effect of interest rates on LTVs for the marginal buyer seems to be extremely weak. This conclusion is consistent with the examples in Bernanke (2010), who argues that the availability of exotic mortgage products and the desire to postpone mortgage payments—rather than the level of the nominal interest rate—were the primary driver of the mortgage choice during the housing boom of the early 2000s.

5.3.2 Monetary Policy Response to House Prices

The result in the previous section is also related to another aspect of monetary policymaking that has been reevaluated after the crisis. Whether central banks should set interest rates taking into account asset prices has been the subject of a long-standing debate. The consensus before the recent financial crisis, both among academics and policymakers, had been that

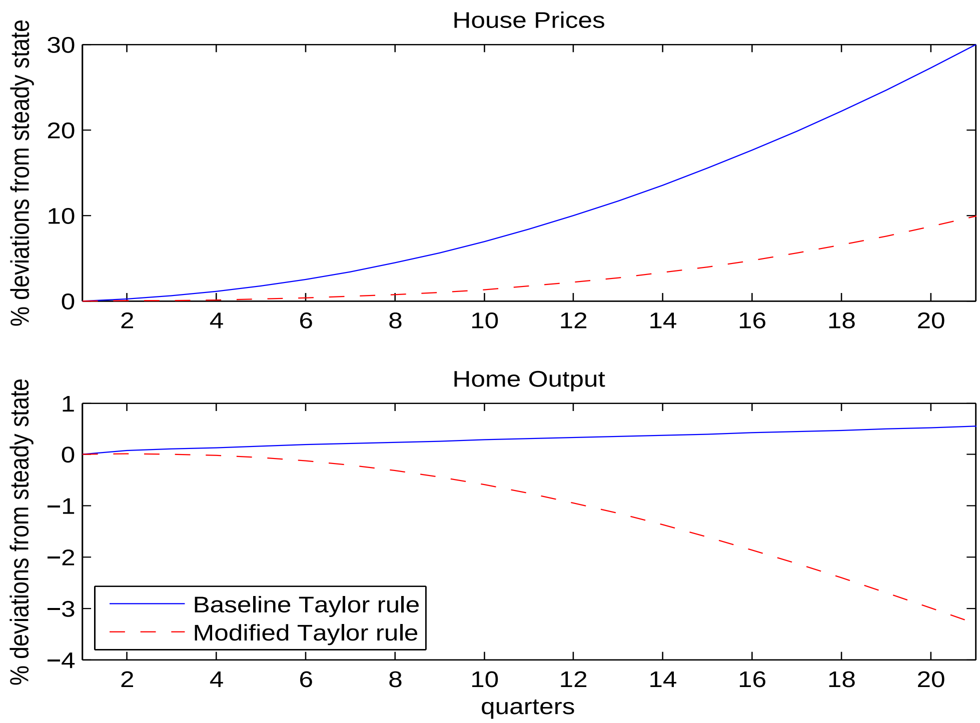

Figure 12: Response of Home country output and headline inflation to the financial deregulation experiment under Foreign peg, when the central bank responds to house price appreciation according to rule (17).

monetary policy acts more effectively by "mopping after the fact" (Bernanke and Gertler, 2001; Greenspan, 2002). Albeit dominant, this view was far from universal even before the recent crisis (see, for instance, Roubini, 2006, and the references therein.). The crisis has led several observers to reconsider the consensus (see, for example, Rudebusch, 2005). Perhaps, the Federal Reserve could have prevented the excessive house price appreciation of the first half of the 2000s by increasing the FFR early on. In relation to the previous section, this view would maintain that asset prices are one indicator that central banks should monitor to assess the risk-taking behavior of the financial sector.

A simple approach to evaluate this hypothesis is to augment the baseline interest rate rule (12) with a response to house price appreciation, beyond the weight already included in the index π_{Xt}

$$i_t = \rho_i i_{t-1} + (1 - \rho_i)(\psi_\pi \pi_{Xt} + \psi_y y_{ht}) + \psi_q \Delta q_t + \varepsilon_{it}, \tag{17}$$

with $\psi_q > 0$. As house prices rise, the central bank hikes the nominal interest rate. Besides the standard channel, the monetary contraction makes debt more costly for households to repay, effectively dampening the increase in households leverage.

Consider the same combination of credit and preference shocks that generates the boom in the previous experiments, but abstract from any expansionary monetary policy shocks. Suppose further the Foreign country pegs its nominal exchange rate to the domestic currency, as the previous section suggests that the model fits the data better under this assumption than under a flexible exchange rate regime. The central bank in the Home country follows the modified interest rate rule (17). The rest of the model remains unchanged. The feedback parameter ψ_q is chosen so that the maximum tolerated increase in house prices over the five-year simulation horizon is 10%, one third of the increase absent any response (top panel of Figure 12).

The bottom panel of Figure 12 compares the behavior of Home output in the baseline scenario (a moderate expansion) and in the case in which the central bank aggressively responds to house prices. Clearly, monetary policy is contractionary enough to cause a deep recession. Output eventually drops by more than 3% relative to steady state. Furthermore, the central bank response induces deflationary pressure. The price index P_{Xt} falls by more than 1% (quarterly annualized) at the peak.

Obviously, ex-post, the welfare consequences of a significant but relatively conventional recession are likely to be milder than those of a full-blown financial crisis, especially on certain segments of the population. Ex-ante, however, the optimal policy design is less straightforward. If the interest rate is the only policy tool, any distortion in financial markets will be reflected in a rationale for targeting asset prices. At the same time, however, a systematic element of monetary policy that responds to asset prices may still not be the best option to deal with financial exuberance. Recent research on optimal joint stabilisation and macro-prudential policies moves the frontier in this direction (Collard et al., 2012). Applications to housing in a world in which financial intermediaries securitize mortgages should be of particular interest to provide a better understanding of the conduct of monetary policy before the crisis.

6 Conclusions

Domestic factors, such as credit and preference shocks, can explain the full increase in U.S. house prices between 2000 and 2005, and, at the same, give rise to substantial current account deficits. Contrary to the evidence, however, domestic shocks cannot account for the fall of the real interest rate observed in the data. These two empirical observations—negative correlation between house prices and current account and low real rates—can be reconciled by considering expansionary monetary policy shocks, measured as departures of the nominal interest rate from the predictions of a conventional monetary policy rule. An exchange rate regime based on foreign pegs to the dollar exports U.S. monetary policy to the rest of the world, thus amplifying the effect of domestic expansionary shocks.

Except for the role of Foreign exchange rate pegs, this explanation of house prices booms and current account deficits has its origins in U.S. behavior and policies. This approach contrasts with recent explanations based on the idea of a foreign saving glut. The two theories are not mutually exclusive. If interpreted as a preference shock (more patient Foreign households), the Foreign saving glut has the effect of further depressing the real interest rate, thus strengthening the mechanism at play in this paper. A more structural interpretation of the Foreign saving glut phenomenon would require explicit modeling of the securitization process that generates safe assets in the U.S. but not in emerging market economies (Bruno and Shin, 2012). Nevertheless, even in this case, the effects of financial flows from the rest of world would likely amplify the consequences of looser borrowing constraints and monetary policies in the Home country.

The results clearly suggest a dichotomy in accounting for house prices and the current account on the one hand, and the real interest rate on the other. In the model, the exogenous driving forces are orthogonal to each other. In practice, low interest rates may have encouraged excessive risk-taking by both individuals and financial institutions, fueling the housing bubble and planting the seeds of the crisis. Simple regressions of loan-to-value ratios on policy rates do not support a significant role for monetary policy in explaining the actual deterioration of credit standards. Nevertheless, the risk-taking channel of monetary policy may operate along different dimensions, not yet fully understood. More broadly, investigating the optimal joint design of monetary a macro-prudential policies in an environment with financial frictions, in particular in relation to the housing market, should represent a high priority in the research agenda going forward.

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A Optimality, Equilibrium, Steady State and Approximation

This appendix presents details on the derivation of the optimality conditions for the Home country representative households and firms, lists the equilibrium conditions, briefly discusses the asymmetric steady state and finally provides the first order approximation of the system of equations that characterizes the equilibrium.

Given the assumption of a representative household in each country, borrowing and lending occurs in equilibrium only at the international level. In what follows, the borrowing constraint is always assumed to bind for the Home economy and never for the Foreign economy.

A.1 Optimality Conditions for Households and Firms

Cost Minimization

Expenditure minimization determines the allocation of total consumption between Home and Foreign tradable goods as a function of their relative prices and total demand. Formally, the problem is

$$P_t C_t = \min_{C_{ht}, C_{ft}} P_{ht} C_{ht} + P_{ft} C_{ft},$$

subject to (3). The first order conditions for this problem are

$$C_{ht} = \alpha \left(\frac{P_{ht}}{P_t} \right)^{-\gamma} C_t \qquad \text{and} \qquad C_{ft} = (1-\alpha) \left(\frac{P_{ft}}{P_t} \right)^{-\gamma} C_t, \tag{18}$$

where the resulting price of the aggregate consumption bundle P_t is

$$P_t = \left[\alpha P_{ht}^{1-\gamma} + (1-\alpha) P_{ft}^{1-\gamma} \right]^{\frac{1}{1-\gamma}}. \tag{19}$$

Final goods producers are perfectly competitive. Their cost minimization problem generates the demand for intermediate goods. The problem for these firms is

$$P_{ht} Y_{ht} = \min_{Y_t(h)} \int_0^1 P_t(h) Y_t(h) dh,$$

subject to (8). The first order condition for this problem is

$$Y_t(h) = \left[\frac{P_t(h)}{P_{ht}} \right]^{-\phi_p} Y_{ht}, \tag{20}$$

where the implied price index of the tradable bundle P_{ht} is

$$P_{ht} = \left[\int_0^1 P_t(h)^{1-\phi_p} dh \right]^{\frac{1}{1-\phi_p}}. \tag{21}$$

Labor agencies are also perfectly competitive. Their cost minimization problem generates the demand for differentiated labor inputs. The problem for these firms is

$$W_t L_t = \min_{L_t(i)} \int_0^1 W_t(i) L_t(i) di,$$

subject to (6). The first order condition for this problem is

$$L_t(i) = \left[\frac{W_t(i)}{W_t} \right]^{-\phi_w} L_t, \tag{22}$$

where W_t is the implied aggregate wage index

$$W_t = \left[\int_0^1 W_t(i)^{1-\phi_w} di \right]^{\frac{1}{1-\phi_w}}. \tag{23}$$

Utility Maximization

The representative household maximizes utility (1) subject to the budget constraint (4) and the borrowing constraint (5). Let $\beta^t \lambda_t$ and $\beta^t \lambda_t \Xi_t$ be the Lagrange multipliers on the two constraints. Workers operate in monopolistic competition taking the demand for their generic labor input as given. Therefore, equation (22) becomes an additional constraint for the household problem.

The first order condition for consumption is

$$\omega X_t^{\frac{1}{\epsilon}-\sigma} C_t^{-\frac{1}{\epsilon}} - \lambda_t P_t = 0. \tag{24}$$

The first order condition for housing services is

$$(1-\omega) e^{\eta_t} X_t^{\frac{1}{\epsilon}-\sigma} H_t^{-\frac{1}{\epsilon}} - \lambda_t \mathcal{Q}_t + \beta \mathbb{E}_t(\lambda_{t+1} \mathcal{Q}_{t+1}) + \lambda_t \Xi_t \Theta_t \mathbb{E}_t(\mathcal{Q}_{t+1}) = 0. \tag{25}$$

The first order condition for debt is

$$\lambda_t - \beta(1+i_t)\mathbb{E}_t(\lambda_{t+1}) - \lambda_t \Xi_t (1+i_t) = 0. \tag{26}$$

Wages are set on a staggered basis (Calvo, 1983). The probability of not being able to adjust the wage is ζ_w. The optimality condition for a worker who is able to adjust the wage at time t is

$$\mathbb{E}_t \left\{ \sum_{s=0}^{\infty} (\beta\zeta_w)^s L_{t+s}(i) \left[\lambda_{t+s} \tilde{W}_t(i) - \frac{\phi_w}{\phi_w - 1} L_{t+s}(i)^{\nu} \right] \right\} = 0, \tag{27}$$

where $\tilde{W}_t(i)$ is the optimal reset wage at time t conditional on no future adjustments. Using the labor demand equation (22) and the expression for the marginal utility of consumption (24) into the previous expression yields

$$\mathbb{E}_t \left\{ \sum_{s=0}^{\infty} (\beta\zeta_w)^s \left[\omega X_{t+s}^{\frac{1}{\epsilon}-\sigma} C_{t+s}^{-\frac{1}{\epsilon}} \left(\frac{\tilde{W}_t(i)}{W_{t+s}} \right)^{-\phi_w} \frac{\tilde{W}_t(i) L_{t+s}}{P_{t+s}} - \frac{\phi_w}{\phi_w - 1} \left(\frac{\tilde{W}_t(i)}{W_{t+s}} \right)^{-\phi_w(1+\nu)} L_{t+s}^{1+\nu} \right] \right\} = 0. \tag{28}$$

Equation (28) can be rearranged as to express the relative wage of type i as a function of the ratio between the present discounted value of the marginal disutility of labor and the present discounted value of the real wage in units of marginal utility of consumption

$$\left[\frac{\tilde{W}_t(i)}{W_t} \right]^{1+\phi_w \nu} = \frac{K_{wt}}{F_{wt}}. \tag{29}$$

The terms on the right-hand side of the last expression can be written recursively as

$$K_{wt} = \frac{\phi_w}{\phi_w - 1} L_t^{1+\nu} + \beta\zeta_w \mathbb{E}_t \left[(\Pi_{wt+1})^{\phi_w(1+\nu)} K_{wt+1} \right] \tag{30}$$

and

$$F_{wt} = \omega X_t^{\frac{1}{\epsilon}-\sigma} C_t^{-\frac{1}{\epsilon}} \frac{W_t L_t}{P_t} + \beta\zeta_w \mathbb{E}_t \left[(\Pi_{wt+1})^{\phi_w - 1} F_{wt+1} \right], \tag{31}$$

where $\Pi_{wt} \equiv W_t / W_{t-1}$ represents wage inflation. Expressions (29)-(31) show that the optimal choice of household members who optimally reset their wage in any given period is a function of aggregate variables only. Therefore, in a symmetric equilibrium, all household members who are able to reset their wage at time t make the same choice, i.e. $\tilde{W}_t(i) = \tilde{W}_t$. The aggregate wage index (23) can then be rewritten as to link the optimal reset relative wage to wage inflation

$$\zeta_w (\Pi_{wt})^{\phi_w - 1} + (1 - \zeta_w) \left(\frac{\tilde{W}_t}{W_t} \right)^{1-\phi_w} = 1. \tag{32}$$

Using the first order condition for consumption (24), the first order conditions for housing services (25) becomes

$$Q_t = \left(\frac{1-\omega}{\omega}\right) e^{\eta_t} \left(\frac{H_t}{C_t}\right)^{-\frac{1}{\epsilon}} + \beta \mathbb{E}_t \left[\left(\frac{X_{t+1}}{X_t}\right)^{\frac{1}{\epsilon}-\sigma} \left(\frac{C_{t+1}}{C_t}\right)^{-\frac{1}{\epsilon}} Q_{t+1} \right] + \Xi_t \Theta_t \mathbb{E}_t \left(\Pi_{t+1} Q_{t+1}\right), \quad (33)$$

where $Q_t \equiv \mathcal{Q}_t / P_t$ defines real house prices. Equation (33) consists of a standard part, according to which real house prices are equal to the marginal utility of housing services in units of marginal utility of consumption plus expected discounted future house prices, and a second part which measures the contribution of the borrowing constraint via the shadow price Ξ_t.

Similarly, using again the first order condition for consumption (24), the first order condition for debt (26) becomes

$$(1+i_t)\Xi_t = 1 - \beta(1+i_t)\mathbb{E}_t \left[\left(\frac{X_{t+1}}{X_t}\right)^{\frac{1}{\epsilon}-\sigma} \left(\frac{C_{t+1}}{C_t}\right)^{-\frac{1}{\epsilon}} \frac{1}{\Pi_{t+1}} \right]. \quad (34)$$

Equation (34) shows that the shadow price Ξ_t represents a wedge in the standard consumption Euler equation due to the borrowing constraint.

No Arbitrage

The representative household in the Foreign country solves the same maximization problem with one substantial difference. While the Foreign representative household can purchase Home debt, Foreign debt only circulates domestically. No arbitrage then implies the consumption-based uncovered interest parity condition

$$\mathbb{E}_t \left\{ \left(\frac{X^*_{t+1}}{X^*_t}\right)^{\frac{1}{\epsilon}-\sigma} \left(\frac{C^*_{t+1}}{C^*_t}\right)^{-\frac{1}{\epsilon}} \frac{1}{\Pi^*_{t+1}} \left[(1+i^*_t) - (1+i_t)\frac{\mathcal{E}_t}{\mathcal{E}_{t+1}} \right] \right\} = 0, \quad (35)$$

where $\mathcal{E}_t$ is the nominal exchange rate, defined as the price in Home currency of one unit of Foreign currency. Because of the representative household assumption, Foreign debt is in zero net supply in equilibrium. Additionally, the Foreign country is assumed to be a net saver in international financial markets so that the Foreign borrowing constraint never binds ($\Xi^*_t = 0$, $\forall t$).

Profit Maximization

The optimality condition for a firm able to adjust its price at time t is

$$\mathbb{E}_t \left\{ \sum_{s=0}^{\infty} (\beta\zeta_p)^s \lambda_{t+s} Y_{t+s}(h) \left[\tilde{P}_t(h) - \left(\frac{\phi_p}{\phi_p - 1}\right) \frac{W_{t+s}}{A} \right] \right\} = 0. \quad (36)$$

Using the demand for intermediate goods (20) and the expression for the marginal utility of consumption (24) into the previous expression yields

$$\mathbb{E}_t \left\{ \sum_{s=0}^{\infty} (\beta\zeta_p)^s X_{t+s}^{\frac{1}{\epsilon}-\sigma} C_{t+s}^{-\frac{1}{\epsilon}} \left[\frac{\tilde{P}_t(h)}{P_{ht+s}} \right]^{-\phi_p} \frac{Y_{ht+s}}{P_{t+s}} \left[\tilde{P}_t(h) - \left(\frac{\phi_p}{\phi_p - 1} \right) \frac{W_{t+s}}{A} \right] \right\} = 0. \tag{37}$$

As for wages, equation (37) can be rearranged as to express the optimal reset relative price of variety h as a function of the ratio between the present discounted value of the real marginal cost and the present discounted value of the real marginal revenues

$$\left[\frac{\tilde{P}_t(h)}{P_{ht}} \right] = \frac{K_{pt}}{F_{pt}}. \tag{38}$$

The terms on the right-hand side of the last expression can be written recursively as

$$K_{pt} = \frac{\phi_p}{\phi_p - 1} X_t^{\frac{1}{\epsilon}-\sigma} C_t^{-\frac{1}{\epsilon}} \frac{W_t Y_{ht}}{A P_t} + \beta\zeta_p \mathbb{E}_t \left[(\Pi_{ht+1})^{\phi_p} K_{pt+1} \right] \tag{39}$$

and

$$F_{pt} = X_t^{\frac{1}{\epsilon}-\sigma} C_t^{-\frac{1}{\epsilon}} \frac{P_{ht} Y_{ht}}{P_t} + \beta\zeta_p \mathbb{E}_t \left[(\Pi_{ht+1})^{\phi_p - 1} F_{pt+1} \right]. \tag{40}$$

Expressions (38)-(40) show that the optimal choice of firms who reset their price in any given period is a function of aggregate variables only. Therefore, in a symmetric equilibrium, all firms that reset their price at time t make the same optimal choice, i.e. $\tilde{P}_t(h) = \tilde{P}_t$. The aggregate price index (21) can be rewritten as to link the relative price of variety h to price inflation

$$\zeta_p (\Pi_{ht})^{\phi_p - 1} + (1 - \zeta_p) \left(\frac{\tilde{P}_t}{P_{ht}} \right)^{1-\phi_p} = 1, \tag{41}$$

where $\Pi_{ht} \equiv P_{ht}/P_{ht-1}$ represents domestic inflation.

Market Clearing

The law of one price holds for tradable goods

$$P_{ht} = \mathcal{E}_t P_{ht}^*. \tag{42}$$

Home bias, however, implies that purchasing power parity does not hold (i.e. $P_t \neq \mathcal{E}_t P_t^*$).

Final goods producing firms sell their products in the Home and Foreign market. Goods market clearing requires

$$Y_{ht} = C_{ht} + C^*_{ht} = \alpha \left(\frac{P_{ht}}{P_t} \right)^{-\gamma} C_t + (1-\alpha) \left(\frac{P^*_{ht}}{P^*_t} \right)^{-\gamma} C^*_t, \tag{43}$$

where the second part of (43) uses (18) and its Foreign country counterpart.

As mentioned, the housing stock is fixed in both countries

$$H_t = H \qquad \text{and} \qquad H^*_t = H^*. \tag{44}$$

Market clearing for financial assets requires

$$\mathcal{B}_t + \mathcal{B}^*_t = 0, \tag{45}$$

where $\mathcal{B}^*_t$ represents Foreign country holdings of international debt.

A.2 Equilibrium

The goods market equilibrium pins down Home and Foreign consumption as a function of relative prices and the real exchange rate ($S_t \equiv \mathcal{E}_t P^*_t / P_t$)

$$Y_{ht} = \left(\frac{P_{ht}}{P_t} \right)^{-\gamma} [\alpha C_t + (1-\alpha) S^{\gamma}_t C^*_t]. \tag{46}$$

The Foreign country counterpart of the last equation is

$$Y_{ft} = \left(\frac{P^*_{ft}}{P^*_t} \right)^{-\gamma} \left[(1-\alpha) S^{-\gamma}_t C_t + \alpha C^*_t \right]. \tag{47}$$

Real house prices are

$$Q_t = \left(\frac{1-\omega}{\omega} \right) e^{\eta_t} \left(\frac{H}{C_t} \right)^{-\frac{1}{\epsilon}} + \beta \mathbb{E}_t \left[\left(\frac{X_{t+1}}{X_t} \right)^{\frac{1}{\epsilon}-\sigma} \left(\frac{C_{t+1}}{C_t} \right)^{-\frac{1}{\epsilon}} Q_{t+1} \right] + \Xi_t \Theta_t \mathbb{E}_t \left(\Pi_{t+1} Q_{t+1} \right). \tag{48}$$

The Foreign counterpart of equation (48) is

$$Q^*_t = \frac{1-\omega^*}{\omega^*} \left(\frac{H^*}{C^*_t} \right)^{-\frac{1}{\epsilon}} + \beta^* \mathbb{E}_t \left[\left(\frac{X^*_{t+1}}{X^*_t} \right)^{\frac{1}{\epsilon}-\sigma} \left(\frac{C^*_{t+1}}{C^*_t} \right)^{-\frac{1}{\epsilon}} Q^*_{t+1} \right]. \tag{49}$$

Differently from the Home economy, the borrowing constraint never binds in the Foreign country, therefore $\Xi^*_t = 0$ at all times.

The borrowing constraint (5) pins down the stock of internationally-traded real debt $B_t \equiv$

$\mathcal{B}_t/P_t$

$$(1+i_t)B_t = \Theta_t \mathbb{E}_t(Q_{t+1} H \Pi_{t+1}). \tag{50}$$

The shadow price of the borrowing constraint is

$$(1+i_t)\Xi_t = 1 - \beta(1+i_t)\mathbb{E}_t \left[\left(\frac{X_{t+1}}{X_t} \right)^{\frac{1}{\epsilon}-\sigma} \left(\frac{C_{t+1}}{C_t} \right)^{-\frac{1}{\epsilon}} \frac{1}{\Pi_{t+1}} \right]. \tag{51}$$

No arbitrage pins down the return in international financial markets

$$\mathbb{E}_t \left[\left(\frac{X^*_{t+1}}{X^*_t} \right)^{\frac{1}{\epsilon}-\sigma} \left(\frac{C^*_{t+1}}{C^*_t} \right)^{-\frac{1}{\epsilon}} \left(\frac{1+i^*_t}{\Pi^*_{t+1}} - \frac{1+i_t}{\Pi_{t+1}} \frac{S_t}{S_{t+1}} \right) \right] = 0, \tag{52}$$

while the Euler equation for the Foreign country pins down the return in the Foreign country

$$1 = \beta^*(1+i^*_t)\mathbb{E}_t \left[\left(\frac{X^*_{t+1}}{X^*_t} \right)^{\frac{1}{\epsilon}-\sigma} \left(\frac{C^*_{t+1}}{C^*_t} \right)^{-\frac{1}{\epsilon}} \frac{1}{\Pi^*_{t+1}} \right]. \tag{53}$$

The wage determination process yields a non-linear wage Phillips curve, which combines the optimal choice of household members who reset their wage in any given period and their mass with the aggregate wage index

$$\left(\frac{1-\zeta_w \Pi_{wt}^{\phi_w - 1}}{1-\zeta_w} \right)^{\frac{1+\phi_w \nu}{1-\phi_w}} = \frac{K_{wt}}{F_{wt}}. \tag{54}$$

According to expression (54), wage inflation $\Pi_{wt} \equiv W_t/W_{t-1}$ is a non-linear function of the present discounted value of the marginal disutility of labor K_{wt}

$$K_{wt} = \frac{\phi_w}{\phi_w - 1} L_t^{1+\nu} + \beta\zeta_w \mathbb{E}_t \left[(\Pi_{wt+1})^{\phi_w(1+\nu)} K_{wt+1} \right] \tag{55}$$

and of the present discounted value of the real wage in units of marginal utility of consumption F_{wt}

$$F_{wt} = \omega X_t^{\frac{1}{\epsilon}-\sigma} C_t^{-\frac{1}{\epsilon}} \frac{W_t L_t}{P_t} + \beta\zeta_w \mathbb{E}_t \left[(\Pi_{wt+1})^{\phi_w - 1} F_{wt+1} \right]. \tag{56}$$

Price setting decisions yield a non-linear price Phillips curve, which combines the optimal choice of firms who reset their price in any given period and their mass with the price index for domestic tradable goods

$$\left(\frac{1-\zeta_p \Pi_{ht}^{\phi_p - 1}}{1-\zeta_p}\right)^{\frac{1}{1-\phi_p}} = \frac{K_{pt}}{F_{pt}}. \tag{57}$$

According to expression (57), inflation in the domestic tradable good sector $\Pi_{ht} \equiv P_{ht}/P_{ht-1}$ is a non-linear function of the present discounted value of real marginal costs K_{pt}

$$K_{pt} = \frac{\phi_p}{\phi_p - 1} X_t^{\frac{1}{\epsilon}-\sigma} C_t^{-\frac{1}{\epsilon}} \frac{W_t Y_{ht}}{A P_t} + \beta \zeta_p \mathbb{E}_t \left[(\Pi_{ht+1})^{\phi_p} K_{pt+1} \right] \tag{58}$$

and of the present discounted value of real marginal revenues

$$F_{pt} = X_t^{\frac{1}{\epsilon}-\sigma} C_t^{-\frac{1}{\epsilon}} \frac{P_{ht} Y_{ht}}{P_t} + \beta \zeta_p \mathbb{E}_t \left[(\Pi_{ht+1})^{\phi_p - 1} F_{pt+1} \right]. \tag{59}$$

In each country, the central bank determines the inflation rate via the interest rate rule

$$(1+i_t) = (1+i_{t-1})^{\rho_i} \left[(1+i) \left(\frac{\Pi_{Xt}}{\tilde{\Pi}_t}\right)^{\varphi_\pi} \left(\frac{Y_{ht}}{\tilde{Y}_{ht}}\right)^{\varphi_y} \right]^{1-\rho_i} e^{\varepsilon_{it}}, \tag{60}$$

and

$$(1+i_t^*) = (1+i_{t-1}^*)^{\rho_i} \left[(1+i) \left(\frac{\Pi_{Xt}^*}{\tilde{\Pi}_t^*}\right)^{\varphi_\pi} \left(\frac{Y_{ft}}{\tilde{Y}_{ft}}\right)^{\varphi_y} \right]^{1-\rho_i} e^{\varepsilon_{it}^*}. \tag{61}$$

The inflation rate that enters the monetary policy rule is a weighted average of goods price inflation and nominal house price appreciation

$$\Pi_{Xt} = \Pi_t^{\omega_X} \left(\frac{\mathcal{Q}_t}{\mathcal{Q}_{t-1}}\right)^{1-\omega_X} = \Pi_t \left(\frac{Q_t}{Q_{t-1}}\right)^{1-\omega_X},$$

where the second part of the equality uses the definition of real house prices.

The law of motion of foreign debt (from the resource constraint) pins down the relative price

$$-B_t = -\frac{(1+i_t) B_{t-1}}{\Pi_t} + \left(\frac{P_{ht}}{P_t}\right) Y_{ht} - C_t. \tag{62}$$

The terms of trade ($\mathcal{T}_t \equiv P_{ft}/P_{ht} = P_{ft}^*/P_{ht}^*$) link domestic relative prices in the two countries

$$\left(\frac{P_{ht}}{P_t}\right)^{-(1-\gamma)} = \alpha + (1-\alpha)\mathcal{T}_t^{1-\gamma} \quad \text{and} \quad \left(\frac{P_{ft}^*}{P_t^*}\right)^{-(1-\gamma)} = \alpha + (1-\alpha)\mathcal{T}_t^{-(1-\gamma)} \tag{63}$$

The law of one price in real terms relates the real exchange rate and the terms of trade according to

$$S_t = \frac{\left[\alpha \mathcal{T}_t^{1-\gamma} + (1-\alpha)\right]^{\frac{1}{1-\gamma}}}{\left[\alpha + (1-\alpha)\mathcal{T}_t^{1-\gamma}\right]^{\frac{1}{1-\gamma}}}.$$

Finally, first-differencing the definition of the real exchange rate allows to pin down the nominal exchange rate

$$\frac{S_t}{S_{t-1}} = \frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} \frac{\Pi_t^*}{\Pi_t}. \tag{64}$$

A.3 Asymmetric Steady State

To build an asymmetric steady state in which country H is a net borrower but relative prices, terms of trade and real exchange rate are still equal to one, start with the assumption that the Home country representative household is relative more impatient ($\beta < \beta^*$). Assume that the borrowing constraint is binding for country H but not for country F ($\Xi > 0$ and $\Xi^* = 0$).

Nominal rigidities are absent in steady state. The Home country labor market equilibrium is

$$1 = \frac{\Phi Y_h^{\nu}}{A^{1+\nu} \omega X^{\frac{1}{\epsilon}-\sigma} C^{-\frac{1}{\epsilon}}}. \tag{65}$$

Equilibrium in the market for goods produced in the Home country is

$$Y_h = \alpha C + (1-\alpha) C^*. \tag{66}$$

These two equations, together with their Foreign country counterpart, pin down C, C^*, Y_h and Y_f as a function of productivity and the housing stock (through X and X^*). The appropriate choice of A and A^*, conditional on the housing stock, ensures that in steady state relative prices are equal to one. Obviously, in this asymmetric steady state, trade is not balanced ($Y_h \neq C$ and $Y_f \neq C^*$). From the perspective of country H, the steady state trade balance must be in surplus to repay the positive stock of foreign debt.

No arbitrage implies

$$R = R^* = \frac{1}{\beta^*}. \tag{67}$$

Since the borrowing constraint is binding for country H, debt is equal to

$$B = \Theta \beta^* Q H. \tag{68}$$

The house price equation yields

$$Q = \left(\frac{1-\omega}{\omega}\right) \frac{(H/C)^{-\frac{1}{\epsilon}}}{1-\beta-\Xi\Theta}. \tag{69}$$

Holding consumption constant, a more relaxed borrowing constraint parameter increases house prices and debt, both directly and indirectly. In the Foreign country, the borrowing constraint is not binding, thus house prices are

$$Q^* = \left(\frac{1-\omega^*}{\omega^*}\right) \frac{(H^*/C^*)^{-\frac{1}{\epsilon}}}{1-\beta^*}. \tag{70}$$

The ratio between the housing stocks in the two countries can be chosen so that the steady state house prices are the same.

A.4 Log-Linear Approximation of the Model

Unless otherwise noted, for any given variable Z_t define $z_t \equiv \log(Z_t/Z) \simeq (Z_t - Z)/Z$, where Z is the steady state of Z_t.

The log-linear approximation of the index (2) for the Home and Foreign country gives

$$x_t = \omega \left(\frac{C}{X}\right)^{\frac{\epsilon-1}{\epsilon}} c_t + (1-\omega)\left(\frac{\epsilon}{\epsilon-1}\right)\left(\frac{H}{C}\right)^{\frac{\epsilon-1}{\epsilon}} \eta_t \qquad \text{and} \qquad x_t^* = \omega^* \left(\frac{C^*}{X^*}\right)^{\frac{\epsilon-1}{\epsilon}} c_t^*. \tag{71}$$

In the Cobb-Douglas case, the indexes become $x_t = \omega c_t$ and $x_t^* = \omega^* c_t^*$.

Equilibrium in goods markets can be approximated as

$$y_{ht} = -\gamma p_{ht} + \varsigma_H[\alpha c_t + (1-\alpha)c_R^{-1}(\gamma s_t + c_t^*)] \tag{72}$$

and

$$y_{ft} = -\gamma p_{ft}^* + \varsigma_F[(1-\alpha)c_R(c_t - \gamma s_t) + \alpha c_t^*]. \tag{73}$$

where $\varsigma_i \equiv C_i/Y_i$ is the steady state consumption share of output in country $i = \{H, F\}$ and $c_R \equiv C/C^*$ is relative consumption across countries.

Next, the approximation of the house price equations (48) yields

$$q_t = (1-\beta-\Xi\Theta)\left(\frac{1}{\epsilon}c_t + \eta_t\right) + \beta\left[\left(\frac{1}{\epsilon}-\sigma\right)(\mathbb{E}_t x_{t+1} - x_t) - \frac{1}{\epsilon}(\mathbb{E}_t c_{t+1} - c_t)\right] \\ + \Xi\Theta(\xi_t + \theta_t + \mathbb{E}_t \pi_{t+1}) + (\beta + \Xi\Theta)\mathbb{E}_t q_{t+1}. \tag{74}$$

The Lagrange multiplier on the borrowing constraint introduces a wedge in the Home country Euler equation. A first order approximation of equation (13) gives

$$i_t + \beta R \left[\left(\frac{1}{\epsilon} - \sigma \right) (\mathbb{E}_t x_{t+1} - x_t) - \frac{1}{\epsilon} (\mathbb{E}_t c_{t+1} - c_t) - \mathbb{E}_t \pi_{t+1} \right] + (1 - \beta R) \xi_t = 0. \tag{75}$$

In the Foreign country, the slack borrowing constraint implies that equation (49) becomes

$$q_t^* = \left(\frac{1 - \beta^*}{\epsilon} \right) c_t^* + \beta^* \left[\left(\frac{1}{\epsilon} - \sigma \right) (\mathbb{E}_t x_{t+1}^* - x_t^*) - \frac{1}{\epsilon} (\mathbb{E}_t c_{t+1}^* - c_t^*) \right] + \beta^* \mathbb{E}_t q_{t+1}^*. \tag{76}$$

The approximation of the borrowing constraint (50) is

$$i_t + b_t = \theta_t + \mathbb{E}_t q_{t+1} + \mathbb{E}_t \pi_{t+1}. \tag{77}$$

A first order approximation to country F Euler equation (53) gives

$$i_t^* + \left(\frac{1}{\epsilon} - \sigma \right) (\mathbb{E}_t x_{t+1}^* - x_t^*) - \frac{1}{\epsilon} (\mathbb{E}_t c_{t+1}^* - c_t^*) - \mathbb{E}_t \pi_{t+1}^* = 0. \tag{78}$$

Up to the first order, the no-arbitrage relation (52) can be written as

$$i_t - \mathbb{E}_t \pi_{t+1} = i_t^* - \mathbb{E}_t \pi_{t+1}^* + \mathbb{E}_t s_{t+1} - s_t. \tag{79}$$

The Fisher parity defines the real interest rate in each country

$$r_t \equiv i_t - \mathbb{E}_t \pi_{t+1} \qquad \text{and} \qquad r_t^* \equiv i_t^* - \mathbb{E}_t \pi_{t+1}^*. \tag{80}$$

A first order approximation of the non-linear wage Phillips curve (54) gives

$$\frac{\zeta_w (1 + \phi_w \nu)}{1 - \zeta_w} \pi_{wt} = k_{wt} - f_{wt}. \tag{81}$$

Up to a first order approximation, the present discounted value of the marginal disutility of labor (30) and the real wage in units of marginal utility of consumption (31) are

$$k_{wt} = (1 - \beta \zeta_w)(1 + \nu) \ell_t + \beta \zeta_w \mathbb{E}_t [\phi_w (1 + \nu) \pi_{wt+1} + k_{wt+1}] \tag{82}$$

and

$$f_{wt} = (1 - \beta \zeta_w) \left[w_t + \left(\frac{1}{\epsilon} - \sigma \right) x_t - \frac{1}{\epsilon} c_t + \ell_t \right] + \beta \zeta_w \mathbb{E}_t [(\phi_w - 1) \pi_{wt+1} + f_{wt+1}], \tag{83}$$

where $w_t \equiv \log[(W_t/P_t)/(W/P)]$ stands for the log-deviation of the real wage from its steady state value. Combining the last three expressions gives a standard forward looking wage Phillips curve

$$\pi_{wt} = \kappa_w \left[\nu \ell_t - w_t - \left(\frac{1}{\epsilon} - \sigma \right) x_t + \frac{1}{\epsilon} c_t \right] + \beta \mathbb{E}_t(\pi_{wt+1}), \tag{84}$$

where $\kappa_w \equiv (1-\beta\zeta_w)(1-\zeta_w)/[\zeta_w(1+\phi_w\nu)]$.

For prices, a first order approximation the non-linear Phillips curve (57) gives

$$\frac{\zeta_p}{1-\zeta_p}\pi_{ht} = k_{pt} - f_{pt}. \tag{85}$$

Up to a first order approximation, the present discounted value of marginal costs (39) and marginal revenues (40) are

$$k_{pt} = (1-\beta\zeta_p) \left[\left(\frac{1}{\epsilon} - \sigma \right) x_t - \frac{1}{\epsilon} c_t + w_t + y_{ht} \right] + \beta\zeta_p \mathbb{E}_t(\phi_p \pi_{ht+1} + k_{pt+1}) \tag{86}$$

and

$$f_{pt} = (1-\beta\zeta_p) \left[\left(\frac{1}{\epsilon} - \sigma \right) x_t - \frac{1}{\epsilon} c_t + p_{ht} + y_{ht} \right] + \beta\zeta_p \mathbb{E}_t[(\phi_p - 1)\pi_{ht+1} + f_{pt+1}]. \tag{87}$$

Combining the last three expressions gives a standard forward looking price Phillips curve

$$\pi_{ht} = \kappa_p(w_t - p_{ht}) + \beta\mathbb{E}_t(\pi_{ht+1}), \tag{88}$$

where $\kappa_p \equiv (1-\beta\zeta_p)(1-\zeta_p)/\zeta_p$.

In each country, the central bank determines inflation via a standard interest rate rule

$$i_t = \rho_i i_{t-1} + (1-\rho_i)(\psi_\pi \pi_{Xt} + \psi_y y_{ht}) + \varepsilon_{it} \tag{89}$$

and

$$i_t^* = \rho_i i_{t-1}^* + (1-\rho_i)(\psi_\pi \pi_{Xt}^* + \psi_y y_{ft}) + \varepsilon_{it}^*, \tag{90}$$

where

$$\pi_{Xt} = \pi_t + (1-\omega_X)(q_t - q_{t-1}) \qquad \text{and} \qquad \pi_{Xt}^* = \pi_t^* + (1-\omega_X)(q_t^* - q_{t-1}^*). \tag{91}$$

The dynamics of debt (62) can be approximated as

$$-b_t = -R(i_{t-1} - \pi_t + b_{t-1}) + b_y^{-1}(p_{ht} + y_{ht} - \varsigma_H c_t), \tag{92}$$

where $b_y \equiv B/Y_h$ is the steady state ratio between net foreign debt and GDP for the Home country.

Up to a first order approximation, the real exchange rate is proportional to the terms of trade

$$s_t = (2\alpha - 1)\tau_t. \tag{93}$$

The approximation of equations (63) that link the terms of trade to domestic relative prices is

$$p_{ht} = -(1-\alpha)\tau_t \qquad \text{and} \qquad p_{ft}^* = (1-\alpha)\tau_t. \tag{94}$$

Finally, the approximation of equation (64) that links real and nominal exchange rates is

$$s_t = s_{t-1} + e_t - e_{t-1} + \pi_t^* - \pi_t. \tag{95}$$

B Additional Results

This section shows three additional results. First, the Lagrange multiplier is always positive throughout the simulations. Second, the dynamics of house prices and the current account are a real phenomenon independent of nominal rigidities, but with flexible prices the behavior of inflation and the real interest rate is counterfactual. Third, the results are robust to different values of the elasticity of substitution between consumption of goods and housing services.

B.1 Lagrange Multipliers

Figure 13 reports the evolution of the Lagrange multiplier across experiments. In steady state, the borrowing constraint in the Home is binding, due to the assumption that $\beta < \beta^*$. The implicit assumption to characterize the dynamics of the model is that the shocks are small enough that the borrowing constraint remains binding also outside the steady state. The figure shows that the assumption is satisfied, although in the full simulation under a flexible exchange rate regime, the Lagrange multiplier approaches zero. Furthermore, in the simulation that matches the data more closely (credit + preference + monetary policy shocks under a

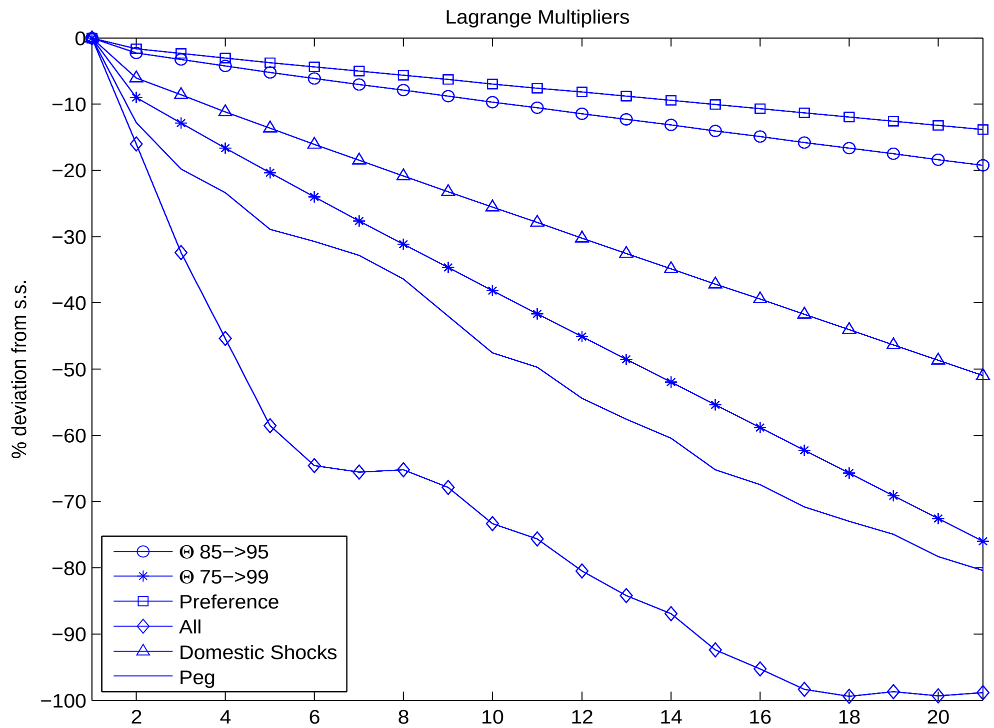

Figure 13: Response of the Lagrange multiplier on the borrowing constraint across experiments. Circles: Moderate financial deregulation (Θ from 85% to 95%). Stars: Extreme financial deregulation (Θ from 75% to 99%). Squares: Preference shocks. Diamonds: Baseline simulation under flexible exchange rates. Triangles: Credit and preference shocks. No marker: Baseline simulation under foreign peg.

foreign peg), the Lagrange multiplier on the borrowing constraint is actually further away from zero.

B.2 The Role of Nominal Rigidities

Figure 14 compares the evolution of house prices, the current account, the real interest rate, and inflation in response to the main experiment under flexible (continuous blue line) and fixed (dashed red line) exchange rates when prices and wages are flexible. The negative correlation between house prices (top-left) and the current account (top-right), as well as their magnitude, does not rely on the presence of nominal rigidities. These two variables largely reflect real forces that are independent of whether prices and wages are sticky or not. Nominal rigidities, however, do play a role in the adjustment of the main macroeconomic variables. By limiting the adjustment of prices and wages, nominal stickiness, in presence of a combination of domestic demand shocks, leads to a boom in aggregate demand which translates into higher consumption and domestic production. Conversely, when prices and wages are flexible, these variables bear most of the adjustment. In particular, expansionary monetary policy shocks fully pass-

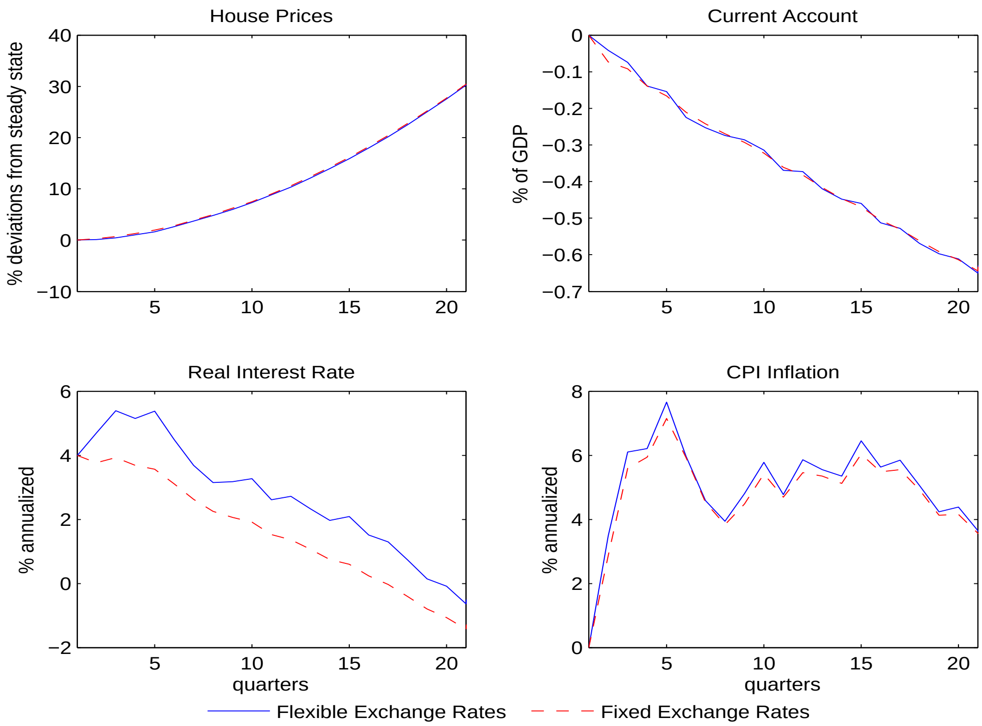

Figure 14: Response of house prices (top-left panel), current account (top-right panel), real interest rate (bottom-left panel), and inflation (bottom-right panel) to the main experiment (combination of credit, preference and monetary policy shocks) under flexible (continuous blue line) and fixed (dashed red line) exchange rates when prices and wages are flexible.

through onto inflation (bottom-right) without any implication for consumption and production. Consequently, current and expected inflation take off, inducing a progressive decline in the real interest rate (bottom-left).

B.3 Robustness

The main conclusion of the paper is robust to changes in most parameters. Detailed results are available upon request. As an example, this section focuses on different values of the elasticity of substitution between consumption of goods and housing services. The main reason is that the calibration of this parameter, set equal to one in the paper, is far from being uncontroversial. While several papers have adopted a Cobb-Douglas specification (i.e. an elasticity equal to one) like in the baseline calibration, the literature supports values both higher and lower than one, based on different readings of the available empirical evidence.

For example, Piazzesi et al. (2007) argue that a Cobb-Douglas formulation for X_t may be too restrictive. Using annual U.S. data since 1929, these authors show that the non-housing share of total consumption is not constant, although its volatility is fairly low. Their calibration

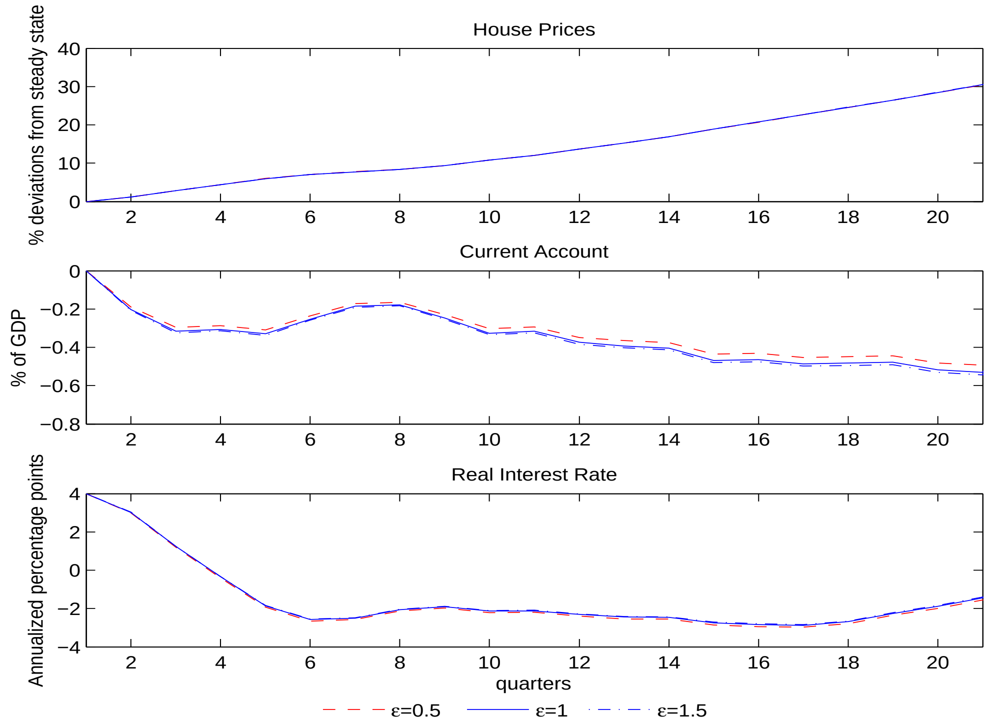

Figure 15: Robustness of the main simulation under fixed exchange rates to different values of the elasticity of substitution between consumption of goods and housing services ($\epsilon = 0.5$: dashed red line; $\epsilon = 1$: continuous blue line; $\epsilon = 1.5$: dashed-dotted black line).

focuses on values of ϵ slightly bigger than one, consistent with the estimates in Ogaki and Reinhart (1998) that lie in the 95% confidence interval [1.04, 1.43]. At the opposite end of the spectrum, Lustig and Van Nieuwerburgh (2004) need a low value of the intertemporal elasticity to match the volatility of U.S. rental prices in an asset pricing model with housing collateral. These authors choose a benchmark is $\epsilon = 0.05$ and explore values up to 0.75.

Figure 15 repeats the baseline experiment for values of the elasticity equal to 0.5 (dashed red line), 1 (continuous blue line—the benchmark calibration) and 1.5 (dashed-dotted black line). An elasticity higher than one, at the upper bound of the confidence interval in the estimates of Ogaki and Reinhart (1998), does not produce significant differences compared to the Cobb-Douglas benchmark calibration. Some small differences are evident for the current account if the elasticity of substitution is smaller than one, in line with the values considered in Lustig and Van Nieuwerburgh (2004). But the magnitudes are not such to invalidate the main conclusion or to point to a substantially different mechanism.