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

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Abstract

Financial deregulation can help rationalize the negative correlation between house prices and current account balance observed in the United States and in several other countries that have experienced the highest degree of turmoil during the recent financial crisis. Lower collateral requirements facilitate access to external funding and increase the demand for consumption and housing. As a consequence, house prices increase and the current account turns negative because households borrow on net from the rest of the world. At the same time, however, the world real interest rate counterfactually raises. Expansionary monetary policy shocks in the United States, amplified by exchange rate pegs to the dollar in emerging economies, keep the world real interest rate low but 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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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 financial sector on the brink of collapse crucially relied on expectations of ever-increasing house prices. Understanding the causes of these house price dynamics is crucial for preventing a repeat of a similar situation in the future.

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 (figure 1). 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).\(^1\) Countries that witnessed the largest house prices booms and current account deficits (such as Greece, Iceland, Ireland,

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\(^1\)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.
Spain and the U.S.) also experienced the highest degree of financial turmoil during the crisis.\textsuperscript{2}

A popular explanation for the negative correlation between current account balance and house prices is the so-called “global saving glut” hypothesis (Bernanke, 2005).\textsuperscript{3} In particular, building on their earlier work, Caballero et al. (2008b) argue 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.

This paper takes a different perspective and shows that financial deregulation, in the form of a progressive relaxation of borrowing constraints, can generate a strong negative correlation between house prices and the current account. This hypothesis is consistent with several pieces of both anecdotal and hard evidence, discussed in section 2, but raises an important issue. An exogenous relaxation of borrowing constraints is akin to a demand shock, which puts upward pressure on the equilibrium real interest rate. In contrast, the evidence shows that real interest rates declined during the early 2000s.

Other papers that find an important role of financial deregulation in accounting for house price booms (and, possibly, current account deficits) have relied, more or less explicitly, on the

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\textsuperscript{2}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).

\textsuperscript{3}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.
global saving glut hypothesis to make the models consistent with the evidence on real interest rates. Capital flows toward the U.S., originating from foreign saving shocks, tend to decrease the real interest, compensating the increase due to the relaxation of borrowing constraints (Favilukis et al., 2011). Boz and Mendoza (2010) assume the U.S. economy simply takes the world real interest rate as given. Instead of literally considering the U.S. economy as small, a more fitting interpretation is that saving glut shocks exactly compensate the upward pressure on the real interest rate due to financial deregulation.

This paper abstracts from saving glut shocks and suggests a different explanation for low interest rates, related to monetary policy in the U.S. and in the rest of the world. During the early 2000s, 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.

The main question that this paper addresses is to which extent expansionary U.S. monetary policy, in a period of financial deregulation, matters for house price booms and current account deficits. 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.4 In this work, 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 explain low real interest rates. From a qualitative perspective, these shocks do 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 financial deregulation, not monetary policy, was the key driver behind the housing boom and the deterioration of the current account. This conclusion is consistent with the recent evidence in Favilukis et al. (2011).

A second implication of monetary policy for the correlation between house prices and the current account concerns the choice of the exchange rate regime by foreign countries. After the Asian crises of the late 1990s, several emerging market (most notably China) and oil producing economies started pegging their nominal exchange rate to the U.S. dollar.5 In a nutshell, these countries import U.S. monetary policy. As a consequence, low U.S. interest rates lead to low global interest rates. Foreign pegs exert additional downward pressure on the real interest rate and impair a real depreciation of the dollar that would help rebalance the U.S. current account deficit.

The analysis relies on a calibrated two-country framework with tradable consumption goods and housing. This model essentially interprets the non-tradable sector in Ferrero et al. (2010) as housing and introduces an endogenous borrowing constraint, as in Kiyotaki and Moore (1997), in the household problem.6 The expected value of housing represents the collateral for private

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4In a small open economy, Iacoviello and Minetti (2003) relate the strength of the impact of monetary policy shocks on house prices to the degree of financial liberalization.

5Dooley et al. (2008) label the resulting international monetary regime “Bretton Woods II”. Their work emphasizes the interplay between managed exchange 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.

6Alternatively, this economy translates a two-sector closed economy model (Iacoviello, 2005; Monacelli, 2009) into
credit. This endogenous borrowing constraint is buffeted by a time-varying parameter which controls the loan-to-value (LTV) requirement and constitutes the key shock in the model. An increase in this threshold, for 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. 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. Quantitatively, the relaxation of borrowing constraints accounts for about two-thirds of the increase in real house prices and almost one-half of the deterioration of the current account during the first half of the 2000s.\(^7\)

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 of the financial deregulation experiment is to generate a boom in house prices and evaluate its consequences for the current account and, most importantly, real interest rates. For example, preference shocks for housing would also be able to deliver a negative correlation between house prices and the current account (Gete, 2009).\(^8\) In this respect, the main contribution of this paper is to show that low nominal interest rates in the U.S. and extensive peg arrangements in the rest of the world explain the low level of real interest rates observed before the recent crisis, both qualitatively and quantitatively.

The findings in this paper complement the role of other factors discussed above, such as the global saving glut hypothesis and preference shocks for housing, 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. Furthermore, while in this paper expectations are fully rational, existing literature shows how learning can amplify the effects of both financial deregulation (Boz and Mendoza, 2010) and low real interest rates (Adam et al., 2011).

The rest of the paper proceeds as follows. Section 2 provides some evidence on the relaxation of credit standards induced by the process of financial innovation. Section 3 presents the model. Section 4 discusses the calibration. Section 5 develops some intuition using the steady state of a tractable special case and introduces the baseline financial deregulation experiment, highlighting the implication for the real interest rate. Section 6 addresses the quantitative importance of overly-accommodative U.S. monetary policy and foreign exchange rate pegs, and evaluates the implications for domestic variables, such as inflation and output. Section 7 tests the robustness of the results to several changes in the parameters. Finally, the last section concludes.
2 Evidence on the Relaxation of Collateral Constraints

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). Fratzscher et al. (2010) adopt the opposite perspective: According to their estimates, together with equity market shocks, house price shocks account for up to 32% of the movements in the U.S. trade balance over a 20-quarter horizon. Arguably, both house prices and the current account are endogenous variables. From a more structural perspective, the key question becomes which underlying fundamentals drive the correlation between these two variables.

The key shock that generates a house price boom and a contemporaneous current account deficit in the model below is an increase of the borrowing constraint parameter: Households can borrow a higher fraction of the collateral value. This relaxation of borrowing constraints captures not only lower LTV ratios but also easier access to loans (both for housing and consumption) for households previously excluded from credit markets, as well as lower transaction costs. The next two sections present some evidence on developments in credit markets in the U.S. and in the rest of the world, with special emphasis on housing finance.

2.1 United States

Figure 3 shows that household debt increased from 58% to 78% of GDP between the beginning of 2001 and the end of 2005. Mortgage debt accounts for 75% of this increase. The other substantial increase is in home lines of credit, which moved from 1 to 4%.

Rajan (2010) argues that easy credit in the U.S. was the consequence of the political response to increasing income inequality. According to this view, the growing role of government-sponsored enterprises (primarily Fannie Mae and Freddie Mac) and the expansion of subprime lending followed from the need to guarantee affordable housing to low income households who are falling behind.

Favara and Imbs (2010) trace 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. Loosely speaking, interstate branching made banks more efficient. More narrowly, the mortgage deregulation process created the possibility to offer credit products across regions with less correlated housing cycles.

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.

In the early 2000s, subprime lending emerged as the most significant development in mortgage finance. In practice, no legally binding definition of subprime lending exists. The Office of the Comptroller of the Currency, the Board of Governors of the Federal Reserve System,

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9See Kumhof and Ranciere (2010) for a formalization of this hypothesis.
10A similar assumption underlay the rating agency valuation models.
the Federal Deposit Insurance Corporation and the Office of Thrift Supervision (2001) jointly issued a document defining as ‘subprime’ those borrowers who “…display a range of credit risk characteristics that may include one or more of the following:

- Two or more 30-day delinquencies in the last 12 months, or one or more 60-day delinquencies in the last 24 months
- Judgment, foreclosure, repossession, or charge-off in the prior 24 months
- Bankruptcy in the last 5 years
- Relatively high default probability as evidenced by, for example, a credit bureau risk score (FICO) of 660 or below (depending on the product/collateral), or other bureau or proprietary scores with an equivalent default probability likelihood
- Debt service-to-income ratio of 50% or greater, or otherwise limited ability to cover family living expenses after deducting total monthly debt-service requirements from monthly income.”

Pinto (2008b,a), a former Fannie Mae’s chief credit officer, points out that official classifi-
<table>
<thead>
<tr>
<th>Year</th>
<th>FHA/VA</th>
<th>Conv/Conf</th>
<th>Jumbo</th>
<th>Subprime</th>
<th>Alt A</th>
<th>HEL</th>
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<tr>
<td>2001</td>
<td>8</td>
<td>57</td>
<td>20</td>
<td>7</td>
<td>2</td>
<td>5</td>
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<td>7</td>
<td>63</td>
<td>21</td>
<td>1</td>
<td>2</td>
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</tr>
<tr>
<td>2003</td>
<td>6</td>
<td>62</td>
<td>16</td>
<td>8</td>
<td>2</td>
<td>6</td>
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<td>4</td>
<td>41</td>
<td>17</td>
<td>18</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>2005</td>
<td>3</td>
<td>35</td>
<td>18</td>
<td>20</td>
<td>12</td>
<td>12</td>
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<td>3</td>
<td>33</td>
<td>16</td>
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<td>2007</td>
<td>4</td>
<td>48</td>
<td>14</td>
<td>8</td>
<td>11</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 1: Mortgage Origination by Product (in %). Source: Abraham et al. (2008).

Table 2 presents direct evidence on the evolution of LTV ratios, broken down by type of mortgage (Prime, Alt A and Subprime) and rate (Fixed and Adjustable). For the prime segment, the average LTV ratio increased by 10 percentage points between 2002 and 2006, for both the fixed- and adjustable-rate types. In both categories, the fraction of mortgages with LTV ratios higher than 80% increased from less than 5% in 2002 to about 25% in 2006. Alt A fixed-rate mortgages featured a similar increase, with LTV ratios higher than 80% roughly doubling between 2002 and 2006. Over the same period, the increase in LTV ratios for Alt A adjustable-
rate mortgages was smaller (of the order of 5 percentage points) but LTV ratios higher than 80% more than doubled, reaching 55% in 2006. For the subprime segment, the increase in LTV ratio was also of the order of 5 percentage points and subprime LTV ratios higher than 80% soared too, especially for the adjustable-rate type.

Several other papers document similar, if not more extreme, patterns for LTVs. Using data from DataQuick that covers 89 metro areas in the United States, Glaeser et al. (2010) find that the median combined LTV ratio on all housing purchases increased 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.

Perhaps not surprisingly, extreme leverage was concentrated outside the prime segment. Duca et al. (2011) calculate average LTVs for first-time homebuyers from the American Housing Survey between 1979 and 2009. The series is stable around 85% until the mid 1990s but displays a clear upward trend (up to 95%) during the period 1995-2005, with most of the increase taking place after 2000. Importantly, the series almost perfectly correlates with the share of outstanding mortgages packaged in private-label (i.e. not issued by Fannie Mae or Freddy Mac) securitized mortgage-backed securities, providing evidence that collateral constraints were primarily relaxed in the non-prime segment. 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 75th percentile throughout this period.

Interestingly, the literature attributes different importance to this phenomenon. Glaeser the

<table>
<thead>
<tr>
<th>Year</th>
<th>Fixed-Rate CLTV</th>
<th>Fixed-Rate CLTV &gt; 80%</th>
<th>Adjustable-Rate CLTV</th>
<th>Adjustable-Rate CLTV &gt; 80%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Prime CLTV</td>
<td>Prime CLTV &gt; 80%</td>
<td>Alt A CLTV</td>
<td>Alt A CLTV &gt; 80%</td>
</tr>
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<td>65.4</td>
<td>3.0</td>
<td>66.5</td>
<td>4.1</td>
</tr>
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<td>2003</td>
<td>63.8</td>
<td>4.4</td>
<td>68.2</td>
<td>10.1</td>
</tr>
<tr>
<td>2004</td>
<td>67.4</td>
<td>7.0</td>
<td>73.5</td>
<td>20.7</td>
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<tr>
<td>2005</td>
<td>70.9</td>
<td>13.4</td>
<td>74.1</td>
<td>21.7</td>
</tr>
<tr>
<td>2006</td>
<td>74.5</td>
<td>23.1</td>
<td>75.3</td>
<td>26.2</td>
</tr>
<tr>
<td>2002</td>
<td>74.7</td>
<td>22.0</td>
<td>74.3</td>
<td>20.8</td>
</tr>
<tr>
<td>2003</td>
<td>71.5</td>
<td>21.4</td>
<td>78.0</td>
<td>33.3</td>
</tr>
<tr>
<td>2004</td>
<td>75.3</td>
<td>29.5</td>
<td>82.6</td>
<td>46.9</td>
</tr>
<tr>
<td>2005</td>
<td>76.2</td>
<td>31.3</td>
<td>83.5</td>
<td>49.6</td>
</tr>
<tr>
<td>2006</td>
<td>79.4</td>
<td>39.6</td>
<td>85.0</td>
<td>55.4</td>
</tr>
<tr>
<td>2002</td>
<td>77.3</td>
<td>38.0</td>
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<tr>
<td>2003</td>
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<tr>
<td>2004</td>
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<td>41.2</td>
<td>85.3</td>
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</tr>
<tr>
<td>2005</td>
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<td>44.5</td>
<td>86.6</td>
<td>64.4</td>
</tr>
<tr>
<td>2006</td>
<td>78.7</td>
<td>44.6</td>
<td>86.7</td>
<td>64.0</td>
</tr>
</tbody>
</table>

Table 2: Evolution of LTV ratios (in %). Source: Abraham et al. (2008). CLTV stands for combined (i.e. first and second mortgage) LTV ratio. CTLV > 80% refers to the fraction of combined LTV ratios larger than 80%.
et al. (2010) argue that the magnitude of the LTV changes is not large enough to account for a significant fraction of the increase in house prices. Geanakoplos (2010b,a) challenges this view, emphasizing the possibility that the increase in leverage increases house prices not only directly but also through a shift in the composition of buyers. Haughwout et al. (2011) support this interpretation by documenting the key role of investors, especially “buy and flip” ones, at the peak of the crisis.

In addition, as mortgage products became riskier due to the increasing participation of subprime borrowers and lower LTV ratios, mortgage rates did not increase. In fact, the spreads between subprime and prime mortgages of similar maturities uniformly decreased between 2000 and 2005, suggesting decreased riskiness (or, with the benefit of hindsight, mis-pricing) of the subprime segment.

The bottom line is that credit market deregulation, supported by the securitization process, provided greater access to mortgage finance at affordable prices for a broader pool of households, both at the extensive (higher share of subprime mortgages) and intensive (lower LTV requirements, availability of HELs) margin. Although not explicitly modeled here, the reduction of transaction costs documented by Favilukis et al. (2011) provides further evidence in support of the process of liberalization in consumer financing.

2.2 Rest of the World

Direct evidence on the relaxation of households’ borrowing constraints for countries other than the U.S. is much more scattered.

The European Mortgage Federation provides some information on housing finance in Europe, although data on LTV ratios are generally not available. One notable exception is Iceland, where LTV ratios increased from 65% to 90% in 2003 before going back to 80% in 2006. Iceland experienced a 60% increase in real house prices between 2001 and 2006, together with one of the largest deteriorations of the current account (more than 20% as a percentage of GDP) ever observed in Western economies.

The U.K experienced an early wave of mortgage market liberalization at the beginning of the 1980s, when down-payment requirements dropped from 25% to 15% (Ortalo-Magné and Rady, 2004). During that decade, real house prices increased by about 70% and the current account moved from a 2% surplus to a 5% deficit.

Outside Europe, Williams (2009) finds evidence that financial liberalizations in the 1980s and 1990s account for about half of the trend increase in real house prices in Australia over the period 1972-2006.

More indirect evidence also points in the direction of a large boom in housing finance in several European countries. Table 3 reports residential mortgage debt as fraction of GDP for a selected group of countries over the period 2001-2006. Iceland, the U.S. and the U.K. featured a similar pattern with mortgage debt growing from about 60 to about 80% of GDP or more. Countries like Spain and Ireland started from lower levels (approximately 30%) but roughly doubled their shares. Mortgage finance in Greece accounted for a small fraction of GDP (12%) in 2001 but reached about 30%, close to the level of France, where mortgage finance increased.
a more moderate 10% over the sample period.

All these examples of significant growth in mortgage debt contrast with the case of Germany, where the share of GDP remained roughly constant just above 50%. The increase in mortgage finance relative to GDP was also small in Japan, from 25% in 1990 to 36% in 2006 (IMF, 2008). Finally, while on the uprise from essentially zero in 1998, mortgage debt was still a small 10% of GDP in China as of 2004 (Jain-Chandra and Chamon, 2010).

Obviously, the boom in mortgage debt can capture several factors, not only financial deregulation. In the case of Spain, for example, the common explanation for the housing boom relies on factors related to housing demand, such as strong income growth, foreign demand for vacation homes and immigration flows (Cortina, 2009). Spanish authorities explicitly limited LTV ratios for securitized mortgages. However, inflated appraisals may have contributed to circumvent these limits so that higher leverage may have amplified demand shocks (Duca et al., 2010). Recent events confirm that Spanish banks extended mortgages to many subprime-like households.

To summarize, credit market liberalizations have greatly stimulated consumer, and in particular housing, finance. The evidence is quite clear for the U.S. and is at least suggestive for several other countries that have experienced contemporaneous house prices booms and current account deficits. Conversely, countries where the process of financial deregulation has been less abrupt have experienced a much lower degree of house price appreciation and often current account surpluses. The next section develops a model in which the relaxation of borrowing constraints plays a key role to account for these facts.

## 3 An Open Economy Model with Borrowing Constraints

Time is discrete and indexed by $t$. Two countries (Home and Foreign) of equal size compose the world economy. In each country, a continuum of measure one of firms produce a final tradable good using a labor aggregate as the only factor of production. The representative household in each country consists of a continuum of measure one of workers who supply differentiated labor inputs and consume a composite of the tradable goods produced in each country 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. 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.

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.

3.1 Household’s 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 $L_t(i)$

$$U_t = \mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \beta^s \left[ \frac{X_t^{1-\sigma}}{1-\sigma} \left( \int_0^1 L_{t+s}(i)_{1+\nu} \right) \right] \right\}$$ (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 $\varepsilon > 0$

$$X_t \equiv \left[ \eta C_t^{\frac{1}{\varepsilon}} + (1 - \eta) H_t^{\frac{1}{\varepsilon}} \right]^{\varepsilon},$$ (2)

where $\eta \in (0, 1)$ represents the share of tradable goods in total consumption.\(^{12}\)

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 $\gamma > 0$

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

where $\alpha \in [0.5, 1)$ is the share of domestic tradable goods.\(^{13}\)

The budget constraint for the representative household in nominal term is

$$P_{ht} C_{ht} + P_{ft} C_{ft} + Q_t H_t - B_t \leq \int_0^1 W_t(i) L_t(i) di + P_t + Q_t H_{t-1} + T_t - (1 + i_{t-1}) B_{t-1},$$ (4)

\(^{12}\)Preference shocks for housing, as in Gete (2009) and Iacoviello and Neri (2010), would take the form of time-varying shares of goods and housing.

\(^{13}\)If $\alpha > 0.5$, preferences for tradable goods exhibit home bias. The Foreign tradable bundle places a weight $\alpha$ on consumption of Foreign tradable goods.
where $P_{jt}$ is the Home price of good $j = \{h, f\}$, $Q_t$ is the price of housing, $W_t(i)$ is the wage for the specific labor input supplied by 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 $B_t$, denominated in the Home currency.

Household’s members perfectly pool their consumption risk 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

$$(1 + i_t)B_t \leq \Theta_tE_t(Q_{t+1}H_t),$$

(5)

where the borrowing constraint parameter $\Theta_t$ is an exogenous shock with mean $\Theta$ and support over the unit interval. The idea behind this type of borrowing constraint is that the Foreign household can only recover a fraction $\Theta_t$ of the collateral in case of default, possibly due to various costs associated with the bankruptcy process.\(^{14}\)

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. 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.\(^{15}\)

### 3.2 Labor Agencies and Wage Setting

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

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

(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

$$L_t(i) = \left[ \frac{W_t(i)}{W_t} \right]^{-\frac{1}{\phi_w}} L_t,$$

(7)

\(^{14}\)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.

\(^{15}\)As mentioned in the introduction, the global saving glut is an alternative—and not necessarily mutually exclusive—explanation which suggests a foreign origin for the capital flows toward the United States. See also the recent work by Acharya and Schnabl (2010) and Bruno and Shin (2012) on the role of global banks in this context.
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 $\zeta_w$. 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 $\lambda_t$ 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.

### 3.3 Firms and Production

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

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

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

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

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 have access to the same constant return technology which uses the labor aggregate $L_t$ as the only factor of production

$$Y_t(h) = AL_t, \quad (10)$$

where $A$ is a constant productivity factor. Intermediate goods producers set prices on a staggered basis, where $\zeta_p$ 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\footnote{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.} 

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

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. 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

$$H_t = H. \quad (11)$$

This assumption gives the model a better chance to match the increase of house prices in response to the financial deregulation experiment described below and, more generally, in response to any shock that would lead to higher housing demand. In practice, the housing boom was also accompanied by a large increase in residential investment. 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, explain the bulk of both trend growth and cyclical house price fluctuations between 1975 and 2006.

### 3.4 Monetary Policy

The central bank sets the short-term nominal interest rate in response to deviations of inflation and output from their targets 

$$
(1 + i_t) = (1 + i_{t-1})^{\rho_i} \left[ (1 + i) \left( \frac{\Pi_t}{\Pi_{t-1}} \right)^{\varphi_\pi} \left( \frac{Y_{ht}}{Y_{ht}} \right)^{\varphi_y} \right]^{1-\rho_i} e^{\varepsilon_{it}}, \quad (12)
$$

where $\rho_i \in (0, 1)$ is the degree of interest rate smoothing, $\varphi_\pi > 1$ and $\varphi_y > 0$ govern the intensity of the interest rate response to inflation and output, respectively, $\Pi_t = P_t / P_{t-1}$ is the inflation rate of goods prices $P_t$, $\Pi_t$ and $Y_{ht}$ are the targets for inflation and output respectively and $\varepsilon_{it}$ is an i.i.d. normal innovation to the interest rate rule with mean zero and standard deviation $\sigma_i$.

### 3.5 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. Household’s members set wages on a staggered basis, taking labor 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. In two-country open economy models, such a steady state is typically a symmetric equilibrium in which net foreign debt 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 pins down net foreign debt). The unattractive feature of a symmetric steady state for current purposes is that, up to a linear approximation, borrowing constraints are irrelevant for house prices dynamics. Real house prices $Q_t = Q_t/P_t$ obey the following forward looking relation

$$Q_t = \left(1 - \frac{\eta}{\eta} \right) \left( \frac{H}{C_t} \right)^{-\frac{1}{\varepsilon}} + \beta E_t \left[ \left( \frac{X_{t+1}}{X_t} \right)^{\frac{1}{\varepsilon}} \left( \frac{C_{t+1}}{C_t} \right)^{\frac{1}{\varepsilon}} Q_{t+1} \right] + \Xi_t \Theta_t E_t (Q_{t+1}).$$  \hspace{1cm} (13)

The first two terms of the right-hand side of (13) are standard. Real house prices are equal to the current marginal utility of housing services in units of marginal utility of consumption plus the discounted expected value of future house prices. The third term measures the contribution of the shadow value of the borrowing constraint to current house prices. A log-linear approximation of expression (13) yields

$$q_t = \left(1 - \frac{\beta - \Xi \Theta}{\varepsilon} \right) c_t + \beta \left[ \left( \frac{1}{\varepsilon} - \sigma \right) (E_t x_{t+1} - x_t) - \frac{1}{\varepsilon} (E_t c_{t+1} - c_t) \right]$$

$$+ \Xi \Theta (\xi_t + \theta_t + E_t \pi_{t+1}) + (\beta + \Xi \Theta) E_t q_{t+1}.$$

If the borrowing constraint is not binding in steady state, the multiplier is equal to zero ($\Xi = 0$). Therefore, up to a first order approximation, changes in the borrowing constraint parameter $\theta_t$ 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 the representative household is relatively more impatient than the Foreign country’s one ($\beta < \beta^*).$ The Home country, thus, is a net borrower in international financial markets. This assumption gives rise to an asymmetric steady state (characterized in appendix A.3) and resuscitates a role for borrowing constraints in affecting house prices dynamics.

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

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17This assumption is quite common in models with borrowers and savers, such as Iacoviello (2005) or Monacelli (2009). Moreover, the evidence suggests quite clearly that the marginal borrower was always taking out the maximum possible loan, in spite of the relaxation of borrowing constraints due to the financial deregulation process.
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.

4 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 ($\beta = 0.98$).18

The coefficient of risk aversion $\sigma$ 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 ($\phi_p = \phi_w = 11$), which are calibrated to match steady state a 10% markup in both the goods and labor market. The price and wage stickiness parameters are chosen to match an average duration of price and wage contracts of four quarters ($\zeta_p = \zeta_w = 0.75$).

The parameters of the goods consumption basket are fairly standard in the international macroeconomics literature (see, for instance, Obstfeld and Rogoff, 2007). The domestic share of tradable consumption $\alpha$ is set to 0.7 (home bias). The elasticity of substitution between Home and Foreign tradable goods $\gamma$ equals 2.

The intratemporal elasticity of substitution between goods consumption and housing services $\varepsilon$ 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 (2011), indicating that expenditure shares on housing are constant over time and across U.S. metropolitan areas.19 The calibration of this parameter is not uncontroversial. Section 7.2 discusses the robustness of the results to alternative values for this elasticity sometimes used in the literature.

Conditional on the elasticity of substitution, the parameter $\eta$ is chosen to match a consumption share of total expenditure of about 80%, which is in line with the average for the U.S. from 1929 to 2001 (Piazzesi et al., 2007). The steady state consumption share of total expenditure in the Home country is20

$$\left(1 + \frac{QH}{C}\right)^{-1} = \left[1 + \left(\frac{1 - \eta}{\eta}\right) \frac{(H/C)^{1-H}}{1 - \beta - \Xi \Theta}\right]^{-1}$$

In the Cobb-Douglas case, the mapping between $\eta$ and the consumption share of total expenditure is independent of the stock of housing and the steady state level of consumption (except for the small indirect effect via the steady state Lagrange multiplier $\Theta$). The relative stock of housing is adjusted so that in steady state the level of house prices in the two countries is the same.

18 These values coincide with the assumed discount factors of savers and borrowers in the closed economy model of Monacelli (2009).
19 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.
20 A similar expression holds for the Foreign country, with the difference that $\Xi^* = 0$. 

17
Based on the evidence in section 2, a steady state borrowing constraint parameter $\Theta$ of 70% seems to characterize quite appropriately the period before credit market deregulation. The stochastic process for the borrowing constraint is assumed to follow an AR(1) process with persistence close to one (0.9999) and i.i.d. innovations $\sim \mathcal{N}(0, 1)$. The idea behind a near unit root process for the borrowing constraint parameter is to capture, in a reduced form, 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 new regime). This assumption plays a crucial role for the quantitative results. If agents anticipate that shocks to the borrowing constraint are mean-reverting, albeit fairly persistent, the boom in house prices becomes about 40% smaller. Conversely, the consumption boom remains about 90% of the baseline case. As the persistence of the financial liberalization process declines, agents switch their consumption from durables (housing) to non-durables (goods).

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 $A/A^*$. Finally, 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 $\rho_i$ is set equal to 0.7. As in Taylor (1993), the response to inflation $\psi_\pi$ equals 1.5 while the response to output $\psi_y$ equals 0.5.

5 The Effects of Relaxing the Borrowing Constraint

The process of financial deregulation corresponds to a relaxation of the collateral constraint parameter $\Theta$ so that households can borrow a higher fraction of the expected value of their house.

A simplified version of the model helps develop the intuition for the mechanism that leads to a house price boom and a current account deficit. 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 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.\(^{21}\)

In a steady state with binding borrowing constraint, the real value of the housing stock in this economy is

$$Q_H = \frac{(1 - \eta)C}{\eta(1 - \beta - \Xi \Theta)}, \quad (14)$$

where $\Xi = (1 - \beta R)/R$. The borrowing constraint at equality requires that debt is equal to a

\(^{21}\) Boz and Mendoza (2010) study the dynamics of this economy when agents must learn the true persistence of the borrowing constraint parameter, which follows a two-state Markov process.
fraction of the discounted real value of the housing stock

\[ B = \frac{\Theta Q H}{R}. \]  

(15)

Holding consumption constant, a permanent increase in the borrowing constraint parameter \( \Theta \) 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.\(^{22}\)

In order to provide a full quantitative analysis of the financial deregulation experiment, the two-country model is approximated up to the first order about the asymmetric steady state described in section 3.5. Appendix A.4 lists the system of log-linear equations that characterize the equilibrium. One limitation of the small open economy version of the model is that the real interest rate is exogenous. The two-country model allows for a comparison of the interest rate dynamics in response to financial deregulation with the data.

The increase in the borrowing constraint parameter occurs gradually over time—a reduced-form approach to capture the possibility that in reality households slowly “learned” the transition to a new regime of more relaxed credit standards. The borrowing constraint parameter starts at 70\% in the initial steady state and progressively moves up to 99\% over a five-year horizon (2001-2005).\(^{23}\)

At its peak, the borrowing constraint parameter takes more extreme values than the evidence on median LTV ratios suggests.\(^{24}\) However, these extreme values capture the fact that 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. Additionally, while the model has a stationary population of households who continuously refinance their loans, in practice high LTVs allowed many new borrowers who previously could not afford a loan to become homeowners. 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) and the emergence of home equity loans (Mian and Sufi, 2011).

More generally, as mentioned in the introduction, the main objective of this paper is to

\(^{22}\)Simulations of a permanent increase of the collateral constraint in the 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.

\(^{23}\)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 are not particularly sensitive to the assumption about the speed of reversion to the initial steady state. Households perceive changes in the value of the borrowing constraint as permanent due to its near unit root process.

\(^{24}\)Favilukis et al. (2011) also consider a deregulation experiment which leads to an almost-complete relaxation of borrowing constraints.
generate a boom in house prices and a current account deficit broadly consistent with the data and evaluate the consequences for interest rates. In this respect, a combination of less extreme financial deregulation (perhaps more tightly calibrated to the evidence on LTV ratios) and preference shocks (either for housing or to the degree of patience) would achieve the same purpose, although the identification of preference shocks would pose other types of challenges. In addition, a house price boom driven by a single shock allows for a cleaner analysis of the marginal contribution of monetary policy shocks, which is the main contribution of this paper.

Figure 4 shows the results of the financial deregulation experiment for a number of selected variables. A higher value of $\Theta$ allows households in the Home country to borrow more for a given value of the collateral. By construction, borrowing occurs in international financial markets only. Therefore, foreign debt increases (top-left) and the current account turns negative (middle-left). At the same time, higher leverage translates into higher demand for consumption of both goods (middle-right) and housing. Because the stock of housing is fixed, house prices absorb the adjustment in full (top-right), providing the endogenous component to the relaxation of borrowing constraints. As resources flow into the Home country and the current account turns negative, the real exchange rate appreciates (bottom-left), while external imbalances are partly mitigated by the increase in the real interest rate (bottom-right).

The simulation accounts for about two-thirds of the increase in the real FHFA house price index and for almost one half of the deterioration of the U.S. current account as a percent of

Figure 4: Simulated path of selected variables in response to a temporary change in the borrowing constraint parameter $\Theta$ from 70% to 99% over five years.
GDP between 2001q1 and 2005q4.\textsuperscript{25} The model generates an almost perfect (-0.98) negative correlation between house prices and the current account balance.

The increase in net foreign debt (10\%) is of the same order of magnitude as in the data (see the updated and extended version of the dataset constructed by Lane and Milesi-Ferretti, 2007). Interestingly, the simulation is also qualitatively consistent with two other features of the data before the recent crisis: (i) A level of consumption well above trend for the entire duration of the house price boom and deterioration of the current account; (ii) The appreciation of the real dollar against a basket of currency of U.S. trading partner, at least for the early 2000s.\textsuperscript{26}

The main counterfactual feature of the simulation in figure 4 is the behavior of the real interest rate. In the model, the real interest rate increases because the relaxation of the collateral constraint stimulates aggregate demand and induces households to anticipate their consumption. However, all available empirical measures point to a decline in short and long-term real interest rates during the early 2000s (figure 5).\textsuperscript{27}

In most of the recent literature on global imbalances, the persistent drop in the real interest rate is typically a consequence of the “saving glut” that originated in Asian economies after the financial crisis of the late 1990s (Bernanke, 2005; Caballero et al., 2008a). As mentioned, other papers that investigate the role of lower collateral requirements for house price booms and current account deficits (Boz and Mendoza, 2010; Favilukis et al., 2011) have also relied to some extent on this idea. The next section explores a different (and potentially complementary) rationale for low real interests at the world level.

6 The Role of Monetary Policy in the U.S. and Abroad

The financial deregulation process that started in the U.S. during the late 1990s and gained full traction in the first half of the 2000s can account for the strong negative correlation between house prices and the current account. 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 are 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, monetary policy shocks may have contributed to stimulate demand beyond what would be normally considered appropriate according to a standard interest rate rule (Taylor, 1993). Therefore, monetary policy may be responsible not only for low interest rates but also

\textsuperscript{25}To the extent that house prices in the model reflect the value of land, the increase generated in the simulation is consistent with the finding in Davis and Heathcote (2007) that the value of land, and not the value of structures, accounts for most of the run-up in house prices observed in the data.

\textsuperscript{26}After being roughly stable in the early 1990s, the broad real dollar appreciated between mid 1995 and early 2002.

\textsuperscript{27}Part of this decline may be due to forces operating at very low frequencies, such as demographic trends (Ferrero, 2010; Favero et al., 2011).
Figure 5: Top panel: The short-term real rate is calculated as the nominal yield on a 1-year T-bill minus expected inflation from the Survey of Professional Forecasters. Bottom panel: The long-term real interest rates are derived from TIPS (U.S. Treasury Inflation Protected Securities that pay a given interest rate—the implied real interest rate—plus the realized CPI) at different maturities. Source: DLX/Haver, Federal Reserve Bank of Philadelphia and author’s calculations.
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 their control on domestic interest rates.\textsuperscript{28} 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.
6.1 Easy U.S. Monetary Policy

Figure 6 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

\[ i_t = \rho_i i_{t-1} + (1 - \rho_i) (\psi \pi_t + \psi y_{ht}) + \varepsilon_{it}, \tag{16} \]

where \( i_t \) is the effective FFR, \( \pi_t \) is the year-over-year CPI inflation rate and \( y_t \) is the deviation of real GDP from potential output as measured by the CBO. The difference between the red line and the green line is the value of the smoothing parameter \( \rho_i \), which is set equal to zero in first case and equal to 0.7 as in the baseline calibration in the second case.

Figure 6 captures the essence of the criticism in Taylor (2008). Between 2001 and 2005, U.S. monetary policy was excessively accommodating compared to the prescriptions of an interest rate rule that characterized well monetary policy in the previous two decades. Lower interest rates facilitated borrowing and led to higher house prices. According to this view, easy monetary policy is a primary suspect 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. Countries that have experienced the largest deviations have also the highest 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.

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 a relaxation of borrowing constraints with an easy monetary policy stance allows for a quantitative evaluation of the relative importance of these two potential explanations for the boom in house prices and the deficit on the current account.

Figure 7 compares the baseline financial deregulation experiment (dashed red line) with a simulation (continuous blue line) that combines the relaxation of borrowing constraints with the monetary policy shocks calculated as departures of the effective FFR from the prescriptions of (16).\(^{30}\)

The figure highlights how little monetary policy shocks contribute to house price appreciation.
Figure 7: Simulated path of selected variables in response to the baseline change in the borrowing constraint parameter combined with monetary policy shocks derived from the Taylor rule (continuous blue line). The dashed red line corresponds to the change in the borrowing constraint parameter only (baseline experiment).
Figure 8: Simulated path of selected variables in response to the baseline change in the borrowing constraint parameter combined with monetary policy shocks derived from the Taylor rule (continuous blue line). The dashed red line corresponds to the response to monetary policy shocks only.

and the deterioration of the current account. The process of financial deregulation remains the driving force. Monetary policy shocks, however, play an important role in the dynamics of consumption, the real interest rate and the real exchange rate. Because inflation expectations are anchored (the systematic part of the monetary policy rule is unchanged), low nominal rates translate into low real rates (bottom-right panel) which stimulate consumption on top of the boost provided by the financial deregulation process.\(^{31}\) The depreciation of the real exchange rate largely reflects the depreciation of the nominal exchange rate induced by the expansionary monetary policy shocks in the Home country.

The limited role of monetary policy shocks in accounting for the correlation between house prices and the current account is even more strikingly visible from figure 8, that compares the simulation with both borrowing constraint and monetary policy shocks (continuous blue line) against a simulation with monetary shocks only (dashed red line). At a qualitative level, easy monetary policy does generate a negative correlation between house prices and the current account, although significantly smaller than in the data (equal to -0.29). The magnitudes of the changes in each of the variables, however, are negligible. House prices increase slightly more than 2% at the peak while the maximum current account deficit is 0.2%. Conversely, monetary

\(^{31}\)Stable inflation expectations are key for this story. If low nominal interest rates had triggered higher inflation expectations, real interest rates would have not dropped significantly. See section 6.3 for further details.
policy shocks lead to a much larger boom in consumption than in the baseline experiment.

Another limitation of considering only monetary policy shocks as the main driver of the adjustment process is the unequivocal depreciation of the real exchange rate. To be sure, the effect is small (less than 1%), and even more so in the simulation that combines monetary policy and borrowing constraint shocks. In the data, the broad real dollar appreciated in the early 2000s, depreciated between early 2002 and the end of 2003 and remained roughly stable in 2004-2005.

Expansionary monetary policy shocks depreciate the real value of the Home currency because of the uncovered exchange rate parity condition. To the extent that in the data such a relation is systematically violated, this model confronts the same issue as the vast majority of open economy macroeconomic frameworks. This problem, however, will be less severe in the next section, where the Foreign country is assumed to peg its exchange rate to the Home currency.

### 6.2 Foreign Exchange Rate Pegs

One important feature of the international monetary system since the early 2000s 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.\footnote{See the International Monetary Fund exchange rate regime classification, summarized for the period 1970-2007 in \textit{Reinhart and Rogoff} (2009).}

\textit{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 9).

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 be 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 generated by the financial liberalization process.

Figure 10 compares the simulation with borrowing constraint and monetary policy shocks under a flexible exchange rate as in the previous section (continuous blue line) with the case (dashed red line) in which the monetary authority of country F follows an exchange rate peg ($E_t = \varepsilon$).

The fixed exchange rate arrangement in the rest of the world does not change the dynamics

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure10}
\caption{Simulated path of selected variables in response to the baseline change in the borrowing constraint parameter combined with monetary policy shocks derived from the Taylor rule under flexible (continuous blue line) and fixed (dashed red line) exchange rates.}
\end{figure}
of house prices and the current account. The real interest rate, however, substantially drops by about 4% at the trough. This magnitude is fairly consistent with the data (compare with the top panel of figure 5). Similarly, the real exchange rate appreciates during the first year, roughly by 3%, and remains stable thereafter before exhibiting a tendency to depreciate toward the end of the sample. The initial appreciation of the real exchange rate limits the consumption boom, especially during the first two years of the simulation.

A pure peg in the rest of the world may be an extreme characterization of the true international system of exchange rates. A perhaps more realistic approach would be to assume that the Foreign country Taylor rule places a non-zero 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 \( \psi_e = 3 \), both the appreciation of the real exchange rate and the drop in the real interest rate are 1% smaller than in the case of a pure peg, while the increase in consumption is about 1% bigger.

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 and of the real exchange rate, without substantially affecting the dynamics of house prices and the current account.

6.3 Implications for Inflation and Output

Most of the analysis so far has focused on the evolution of international variables, such as the current account and the real exchange rate, and asset prices, such as house prices and 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 some implications for domestic variables, such as inflation and output, which are at the core of central banks’ mandates.

6.3.1 Inflation

An important aspect of the period 2000-2005 is the behavior of actual and expected inflation (top panel of figure 11). Part of the reason why the Federal Reserve decided to keep nominal interest rates low for “a considerable period” was the so-called deflationary scare of 2001, when year-over-year headline CPI inflation declined from 3.4% to 1.2% within twelve months. If monetary policy was indeed overly accommodative, the excessive stimulus could have induced inflation to take off. In the data, inflation remained well contained, moving from the lows of late 2001 back up to 3% over the course of the next four years. During the same period, one-year ahead inflation expectations from the Survey of Professional Forecasters remained remarkably
Figure 11: Top panel: Actual and expected (from Survey of Professional Forecasters) year-over-year percentage change of headline Consumer Price Index Inflation in the data. Bottom panel: Year-over-year headline inflation in the model under flexible exchange rates and under foreign peg.
stable within the range 2.2.5%.33

The bottom panel of figure 11 shows that the simulation produces a path for inflation fairly consistent with the data, except for the disinflationary pressures that are not part of the model. Over the five-year horizon of the simulation, CPI inflation rises less than 1% on an year-over-year basis.34 Under flexible exchange rates, the initial increase is less pronounced and inflation hovers about 40 basis points above its steady state value, as a consequence of the expansionary monetary policy shocks and the depreciation of the exchange rate. Conversely, if the Foreign country pegs its nominal exchange rate to the Home currency, the spike at the beginning of the simulation is slightly more significant but inflation moderates thereafter, as the peg prevents the nominal exchange rate from depreciating.

6.3.2 Output

A second implication for domestic variables is related to the potential response of monetary policy to asset prices. Whether central banks should set interest rates taking into account

33Long-term expectations are stable by construction in the model because the monetary policy rule responds more than one-to-one to inflation. Conversely, temporary inflationary shocks generate expectations of deflation in the short-term (and vice versa), which tend to be persistent due to the inertia in the nominal interest rate.

34Before the financial deregulation experiment inflation is assumed to be at its steady state value. Therefore, year-over-year inflation equals zero for the first three quarters of the simulation.
exchange rate or stock market movements has been the subject of a long-standing debate. The consensus before the recent financial crisis, both among academics and policymakers, had been that monetary policy acts more effectively by “mopping after the fact” (Bernanke and Gertler, 2001; Greenspan, 2002). 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.

A simple approach to evaluate this hypothesis is to augment the baseline interest rate rule (12) with a response to house price appreciation

\[ i_t = \rho_i i_{t-1} + (1 - \rho_i)(\psi_i \pi_t + \psi_y y_t) + \psi_q \Delta q_t + \varepsilon_{it}, \]

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, effectively dampening the increase in households’ leverage.

Consider the same financial deregulation experiment as in the original simulation, hence abstracting from any expansionary monetary policy shocks. Suppose further the central bank in the Home country follows the modified interest rate rule (17) while the Foreign country pegs its nominal exchange rate to the domestic currency. The rest of the model remains unchanged. The feedback parameter \( \psi_q \) is chosen so that the maximum tolerated increase in house prices over the deregulation horizon is 10%, half of the increase absent any response.

Figure 12 shows the behavior of output and inflation in this case. Clearly, monetary policy is contractionary enough to cause a deep recession. Output eventually drops by 4% relative to steady state and deflation is of the same order of magnitude. One caveat is that the price index considered here to calculate headline inflation puts no weight on house prices. Yet, if the monetary policy response is such that house prices increase by 10% at most, factoring in the entire increase in house prices would still put headline inflation in negative territory by 0.64% at the peak. Obviously, the response of output would be unchanged.

7 Robustness

This section shows that the results are robust to variations in a number of parameters of particular interest.

7.1 The Role of Nominal Rigidities

The negative correlation between house prices and the current account 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 consumption, output and inflation. This result is intuitive. By limiting the

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35 Albeit dominant, this view was far from universal even before the recent crisis. See, for instance, Roubini (2006) and the references therein.

36 This calculation relies on the CPI weight of owner’s equivalent rent. Using the PCE weight instead (see McCarthy and Peach, 2010) would imply a 2.46% deflation at the peak.
adjustment of prices and wages to the financial deregulation experiment, nominal stickiness leads to a boom in aggregate demand which translates into higher consumption and domestic production.

Figure 13 compares the evolution of consumption, output and inflation in the Home country under the baseline financial deregulation experiment with (continuous blue line) and without (dashed red line) nominal rigidities. The consumption boom discussed earlier essentially disappears when prices and wages are fully flexible. Absent nominal rigidities, the higher volatility in prices and wages reduces the need for changes in real quantities. In this case, output in country H actually falls because Home goods become more expensive much faster. As a result, the increase in inflation becomes non-negligible.

Interestingly, this simulation also highlights how the deviations of inflation from trend discussed in the previous section and illustrated in the bottom panel of figure 11 almost entirely depend on monetary shocks. The model, therefore, attributes a very clear-cut role to financial deregulation in explaining the boom in house prices and the current account deficits, and to monetary policy in explaining the increase in inflation.
7.2 Goods and Housing: Complements or Substitutes?

As mentioned earlier, the value of the elasticity of substitution between consumption of goods and housing services is the subject of an open debate. While several papers have adopted a Cobb-Douglas specification (i.e. an elasticity equal to one) like in the baseline calibration, values both higher and lower than one have also been used.

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 focuses on values of $\varepsilon$ 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 $\varepsilon = 0.05$ and explore values up to 0.75.

Figure 14 repeats the baseline experiment for values of the elasticity equal to 0.15 (dashed green line), 1 (continuous blue line—the benchmark calibration) and 1.5 (dashed-dotted red 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 differences are evident if the elasticity of substitu-
tion is very small, in line with the value in Lustig and Van Nieuwerburgh (2004). A low elasticity of substitution generates a smaller initial increase in house prices. The house price boom, however, continues well after the financial deregulation process is over (about ten quarters). In this case, house prices rise by 40% at the peak. The deterioration of the current account is also larger, in spite of a smaller increase in consumption. The reason is that domestic output falls, due to the larger appreciation of the real exchange rate. Finally, a further consequence of the more moderate behavior of consumption is the modest rise in the real interest rate. Even in this case, though, the differences are quantitatively not dramatic.

The bottom line is that the results are quite robust to alternative values of the elasticity of substitution between consumption of goods and housing services, a fairly controversial parameter in the literature. If anything, low values of this elasticity generate larger quantitative effects of financial deregulation on house prices and the current account than in the baseline calibration and partially limit the counterfactual increase in the real interest rate.

7.3 Other Parameters

The results are also robust to changes in several other parameters. For example, changes in the elasticity of substitution between Home and Foreign goods \( \gamma \) are almost irrelevant for the dynamics.

Lower degrees of relative risk aversion \( \sigma \) imply more responsiveness of Foreign consumption to domestic financial liberalizations (and vice versa). Interestingly, Home consumption is much less sensitive to changes in this parameter. For the Home country, the wedge in the Euler equation introduced by the borrowing constraint absorbs most of the adjustment. The other variables are almost unaffected by different calibrations of this parameter.

Changes in the inverse Frisch elasticity of labor supply \( \nu \) matter, mostly for inflation, if this parameter takes a relatively low value (e.g. close to one). In this case, domestic inflation in both countries becomes more sensitive to the financial deregulation experiment because the wealth effect associated with the shock reduces labor supply, thus increasing firms’ marginal costs. Remember, however, that in the absence of monetary policy shocks, the inflationary consequences of relaxing the borrowing constraint parameter are modest. The dynamics of house prices and the current account coincide with the baseline case.

Values of the share of domestic consumption goods \( \alpha \) in the range \([0.6, 0.8]\) also do not substantially alter the main picture. Again, the evolution of house prices and the current account in response to the baseline financial deregulation experiment is unchanged. Domestic consumption responds more the higher home bias is. Consequently, the real interest rate increases more and the appreciation of the Home currency is larger. When home bias is large, the Home country experiences some deflationary pressures, partly driven by the appreciation of the domestic currency. Additionally, a high degree of home bias implies that the consumption boom induced by the relaxation of borrowing constraints mostly pertains to domestic goods. The monetary authority leans against the higher demand increasing the nominal interest rate. As a consequence, domestic inflation falls in response to the more aggressive response of monetary policy.
8 Conclusions

A relaxation of borrowing constraints, in the form of lower collateral requirements, can explain a significant fraction of the increase in U.S. house prices and, at the same, give rise to substantial current account deficits. This explanation rationalizes the negative correlation observed in the data between house prices and current account balances in the U.S. and in several other developed and developing economies. Contrary to the evidence, however, financial deregulation shocks lead the real interest rate to increase. These two empirical observations—negative correlation between house prices and current account and low real rates—can be reconciled by considering accommodative monetary policy shocks as departures of the nominal interest rate from 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.

The results clearly suggest a dichotomy in accounting for the main observable variables object of this study. While financial deregulation explains 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 empirical evidence supports this hypothesis (e.g. De Nicolò et al., 2010, and the references therein). Cociuba et al. (2012), however, show that 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.

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. 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.
References


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

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

where the resulting price of the aggregate consumption bundle \( P_t \) is

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

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

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

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

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

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

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 \( \beta \lambda_t \) and \( \beta \lambda_t \Xi_t \) 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

\[
\eta X_t^{\frac{1}{1-\sigma}} C_t^{-\frac{1}{1-\sigma}} - \lambda_t P_t = 0. \tag{24}
\]

The first order condition for housing services is

\[
(1-\eta)X_t^{\frac{1}{1-\sigma}} H_t^{-\frac{1}{1-\sigma}} - \lambda_t Q_t + \beta E_t(\lambda_{t+1} Q_{t+1}) + \lambda_t \Xi_t \Theta_t E_t(Q_{t+1}) = 0. \tag{25}
\]

The first order condition for debt is

\[
\lambda_t - \beta(1 + i_t) E_t(\lambda_{t+1}) - \lambda_t \Xi_t (1 + i_t) = 0. \tag{26}
\]

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

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

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

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

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

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

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

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

and

$$ F_{wt} = \eta X_t^{\frac{1}{\gamma} - \sigma} C_t^{\frac{1}{\gamma} - \sigma} \frac{\tilde{W}_t L_t}{P_t} + \beta \zeta_w \mathbb{E}_t \left[ (\Pi_{wt+1})^{\phi_w - 1} F_{wt+1} \right], \quad (31) $$

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

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

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

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

where $Q_t \equiv Q_t/P_t$ 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 $\Xi_t$.

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

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

Equation (34) shows that the shadow price \( \Xi_t \) 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

\[\mathcal{E}_t \left\{ \left( \frac{X_{t+1}^*}{X_t^*} \right)^{\frac{1}{1-\sigma}} \left( \frac{C_{t+1}^*}{C_t^*} \right)^{-\frac{1}{\phi}} \cdot \frac{1}{\Pi_{t+1}^*} \left[ (1 + i_t^*) - (1 + i_t) \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}^*} \right] \right\} = 0, \quad (35)\]

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

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

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

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

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

\[\left[ \frac{\hat{P}_t(h)}{P_{ht}} \right] = \frac{K_{pt}}{P_{pt}}. \quad (38)\]

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

\[K_{pt} = \frac{\phi_p}{\phi_p - 1} \left( X_t^{\frac{1}{1-\sigma}} \right) \frac{W_t Y_{ht}}{A P_t} + \beta \zeta_p \mathcal{E}_t \left[ (\Pi_{ht+1})^{\phi_p} K_{pt+1} \right] \quad (39)\]
and
\[
F_{pt} = X_t^{\frac{1}{1-\sigma}} C_t^{-\frac{1}{1-\sigma}} P_{ht} Y_{ht} + \beta \zeta_p \mathcal{E}_t \left[ (\Pi_{ht+1})^{\phi_p-1} F_{pt+1} \right].
\] (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. \( \hat{P}_t(h) = \hat{P}_t \). The aggregate price index (21) can be rewritten as to link the relative price of variety \( h \) to price inflation
\[
\zeta_p (\Pi_{ht})^{\phi_p-1} + (1 - \zeta_p) \left( \frac{\hat{P}_t}{P_{ht}} \right)^{1-\phi_p} = 1,
\] (41)

where \( \Pi_{ht} \equiv \frac{P_{ht}}{P_{ht-1}} \) represents domestic inflation.

**Market Clearing**

The law of one price holds for tradable goods
\[
P_{ht} = \mathcal{E}_t P_{ht}^*.
\] (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
\[
Y_{ht} = C_{ht} + C_{ht}^* = \alpha \left( \frac{P_{ht}}{P_t} \right)^{-\gamma} C_t + (1 - \alpha) \left( \frac{P_{ht}^*}{P_t^*} \right)^{-\gamma} C_t^*,
\] (43)

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

As mentioned, the housing stock is fixed in both countries
\[
H_t = H \quad \text{and} \quad H_t^* = H^*.
\] (44)

Market clearing for financial assets requires
\[
B_t + B_t^* = 0,
\] (45)

where \( B_t^* \) 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 \( S_t \equiv \mathcal{E}_t P_t^* / P_t \)
\[
Y_{ht} = \left( \frac{P_{ht}}{P_t} \right)^{-\gamma} [\alpha C_t + (1 - \alpha) S_t^* C_t^*].
\] (46)
The Foreign country counterpart of the last equation is
\[ Y_{ft} = \left( \frac{P_{ft}}{P_t} \right)^{-\gamma} \left[ (1 - \alpha) S_t^{-\gamma} C_t + \alpha C_t^\gamma \right]. \] (47)

Real house prices are
\[ Q_t = \frac{1}{\eta} \left( \frac{H}{C_t} \right)^{-\frac{1}{\eta}} + \beta E_t \left[ \left( \frac{X_{t+1}}{X_t} \right)^{\frac{1}{\delta}} \left( \frac{C_{t+1}}{C_t} \right)^{-\frac{1}{\delta}} Q_{t+1} \right] + \Xi_t \Theta_t \mathcal{E} t (\Pi_{t+1} Q_{t+1}), \] (48)

The Foreign counterpart of equation (48) is
\[ Q_{t}^* = \frac{1}{\eta} \left( \frac{H^*}{C_t^*} \right)^{-\frac{1}{\eta}} + \beta^* E_t \left[ \left( \frac{X_{t+1}^*}{X_t^*} \right)^{\frac{1}{\delta}} \left( \frac{C_{t+1}^*}{C_t^*} \right)^{-\frac{1}{\delta}} Q_{t+1}^* \right]. \] (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 \( B_t \equiv B_t / P_t \)
\[ (1 + i_t)B_t = \Theta_t \mathcal{E}_t (Q_{t+1} H \Pi_{t+1}). \] (50)

The shadow price of the borrowing constraint is
\[ (1 + i_t) \Xi_t = 1 - \beta (1 + i_t) E_t \left[ \left( \frac{X_{t+1}}{X_t} \right)^{\frac{1}{\delta}} \left( \frac{C_{t+1}}{C_t} \right)^{-\frac{1}{\delta}} \frac{1}{\Pi_{t+1}} \right]. \] (51)

No arbitrage pins down the return in international financial markets
\[ E_t \left[ \left( \frac{X_{t+1}}{X_t} \right)^{\frac{1}{\delta}} \left( \frac{C_{t+1}}{C_t} \right)^{-\frac{1}{\delta}} \left( \frac{1 + i_t}{\Pi_{t+1}} - 1 + i_t \frac{S_t}{\Pi_{t+1} S_{t+1}} \right) \right] = 0, \] (52)
while the Euler equation for the Foreign country pins down the return in the Foreign country
\[ 1 = \beta^* (1 + i_t^*) E_t \left[ \left( \frac{X_{t+1}^*}{X_t^*} \right)^{\frac{1}{\delta}} \left( \frac{C_{t+1}^*}{C_t^*} \right)^{-\frac{1}{\delta}} \frac{1}{\Pi_{t+1}^*} \right]. \] (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
\[ \left( \frac{1 - \zeta_w \Pi_{w^*}^{-1}}{1 - \zeta_w} \right)^{\frac{\delta + \phi_w}{\delta - \phi_w}} = K_{wt} / F_{wt}. \] (54)

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

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

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

\[
F_{wt} = \eta X_t^\gamma C_t^{-\sigma} \frac{W_t L_t}{P_t} + \beta \zeta_w E_t \left[ (\Pi_{wt+1})^{\phi_w-1} F_{wt+1} \right]. \tag{56}
\]

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

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

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 \( K_{pt} \)

\[
K_{pt} = \frac{\phi_p}{\phi_p - 1} X_t^{\frac{1}{1-\sigma}} C_t^{-\frac{1}{1-\sigma}} \frac{W_t Y_{ht}}{AP_t} + \beta \zeta_p E_t \left[ (\Pi_{ht+1})^{\phi_p K_{pt+1}} \right] \tag{58}
\]

and of the present discounted value of real marginal revenues

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

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

\[
(1 + i_t) = (1 + i_{t-1})^{\rho_i} \left[ (1 + i) \left( \frac{\Pi_t}{\Pi_t} \right)^{\phi_x} \left( \frac{Y_{ht}}{Y_{ht}} \right)^{\phi_y} \right]^{1-\rho_i} e^{\epsilon_{it}}, \tag{60}
\]

and

\[
(1 + i_t^*) = (1 + i_{t-1}^*)^{\rho_i} \left[ (1 + i) \left( \frac{\Pi_t^*}{\Pi_t^*} \right)^{\phi_x} \left( \frac{Y_{ft}}{Y_{ft}} \right)^{\phi_y} \right]^{1-\rho_i} e^{\epsilon_{it}^*}. \tag{61}
\]

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 world resource constraint pins down the real exchange rate

\[
\left( \frac{P_{ht}}{P_t} \right) Y_{ht} + \left( \frac{P_{ft}}{P_{ft}^*} \right) S_t Y_{ft} = C_t + S_t C_t^*. \tag{63}
\]
Equations (46) to (63) characterize the equilibrium in terms of domestic relative prices and the real exchange rate. The terms of trade \( T_t \equiv P_{ft}/P_{ht} = P_{ft}^\star/P_{ht}^\star \) link domestic relative prices in the two countries

\[
\left( \frac{P_{ht}}{P_t} \right)^{-(1-\gamma)} = \alpha + (1-\alpha)T_t^{1-\gamma} \quad \text{and} \quad \left( \frac{P_{ht}^\star}{P_t^\star} \right)^{-(1-\gamma)} = \alpha + (1-\alpha)T_t^{-1(1-\gamma)} \tag{64}
\]

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

\[
\frac{S_t}{S_{t-1}} = \frac{\varepsilon_t}{\varepsilon_{t-1}} \frac{\Pi_t^\star}{\Pi_t} \tag{65}
\]

### 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 \((\beta < \beta^\star)\). Assume that the borrowing constraint is binding for country H but not for country F \((\Xi > 0 \text{ and } \Xi^\star = 0)\).

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

\[
1 = \frac{\Phi Y_h^\nu}{A^{1+\nu} X^\frac{1}{\gamma}-\sigma C^{-\frac{1}{\gamma}}} \tag{66}
\]

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

\[
Y_h = \alpha C + (1-\alpha)C^\star \tag{67}
\]

These two equations, together with their Foreign country counterpart, pin down \(C, C^\star, Y_h\) and \(Y_f\) as a function of productivity and the housing stock (through \(X\) and \(X^\star\)). The appropriate choice of \(A\) and \(A^\star\), 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 \(Y_f \neq C^\star)\). 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

\[
R = R^\star = \frac{1}{\beta^\star} \tag{68}
\]

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

\[
B = \Theta \beta^\star QH \tag{69}
\]

The house price equation yields

\[
Q = \left( \frac{1-\eta}{\eta} \right) \frac{(H/C)^{-\frac{1}{\gamma}}}{1-\beta-\Xi\Theta} \tag{70}
\]

49
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

\[ Q^* = \left( \frac{1 - \eta}{\eta} \right) \frac{C^*/H^*}{1 - \beta^*}. \]  

(71)

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 \( z_t \equiv \log(\frac{Z_t}{Z}) \). The log-linear approximation of the index (2) for the Home and Foreign country gives

\[ x_t = \eta \left( \frac{C}{X} \right)^{\frac{1}{\epsilon}} c_t \quad \text{and} \quad x_t^* = \eta \left( \frac{C^*}{X^*} \right)^{\frac{1}{\epsilon}} c_t^*. \]  

(72)

Equilibrium in goods markets can be approximated as

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

(73)

and

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

(74)

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

\[ q_t = \left( \frac{1 - \beta - \Xi \Theta}{\epsilon} \right) c_t + \beta \left( \frac{1}{\epsilon} - \sigma \right) \left( \mathbb{E}_t x_{t+1} - x_t \right) - \frac{1}{\epsilon} (\mathbb{E}_t c_{t+1} - c_t) \]

\[ + \Xi \Theta (\xi_t + \theta_t + \mathbb{E}_t \pi_{t+1}) + (\beta + \Xi \Theta) \mathbb{E}_t q_{t+1}. \]  

(75)

The Lagrange multiplier on the borrowing constraint introduces a wedge in the Home country Euler equation. A first order approximation of equation (51) gives

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

(76)

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

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

\[ + \beta^* \mathbb{E}_t q_{t+1}^*. \]  

(77)
The approximation of the borrowing constraint (50) is
\[ i_t + b_t = \theta_t + E_t q_{t+1} + E_t \pi_{t+1}. \] (78)

A first order approximation to country F Euler equation (53) gives
\[ i^*_t + \left( \frac{1}{\varepsilon} - \sigma \right) (E_t x^*_t - x^*_t) - \frac{1}{\varepsilon} (E_t c^*_t - c^*_t) - E_t \pi^*_t = 0. \] (79)

Up to the first order, the no-arbitrage relation (52) can be written as
\[ i_t - E_t \pi^*_t = i^*_t - E_t \pi_{t+1} + E_t s_{t+1} - s_t. \] (80)

The Fisher parity defines the real interest rate in each country
\[ r_t \equiv i_t - E_t \pi_t \] and \[ r^*_t \equiv i^*_t - E_t \pi^*_t. \] (81)

A first order approximation of the non-linear wage Phillips curve (54) gives
\[ \frac{\zeta_w(1 + \phi_w \nu)}{1 - \zeta_w} \pi_w = k_w - f_w. \] (82)

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
\[ k_w = (1 - \beta \zeta_w)(1 + \nu) \ell_t + \beta \zeta_w E_t[\phi_w(1 + \nu) \pi_{w+1} + k_{w+1}] \] (83)

and
\[ f_w = (1 - \beta \zeta_w) \left[ w_t + \left( \frac{1}{\varepsilon} - \sigma \right) x_t - \frac{1}{\varepsilon} c_t + \ell_t \right] + \beta \zeta_w E_t[(\phi_w - 1) \pi_{w+1} + f_{w+1}], \] (84)

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
\[ \pi_w = \kappa_w \left[ \nu \ell_t - w_t - \left( \frac{1}{\varepsilon} - \sigma \right) x_t + \frac{1}{\varepsilon} c_t \right] + \beta E_t(\pi_{w+1}), \] (85)

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
\[ \frac{\zeta_p}{1 - \zeta_p} \pi_p = k_p - f_p. \] (86)

Up to a first order approximation, the present discounted value of marginal costs (39) and
marginal revenues (40) are
\[ k_{pt} = (1 - \beta \zeta_p) \left[ \left( \frac{1}{\varepsilon} - \sigma \right) x_t - \frac{1}{\varepsilon} c_t + w_t + y_{ht} \right] + \beta \zeta_p E_t (\phi p_{ht+1} + k_{pt+1}) \] (87)
and
\[ f_{pt} = (1 - \beta \zeta_p) \left[ \left( \frac{1}{\varepsilon} - \sigma \right) x_t - \frac{1}{\varepsilon} c_t + p_{ht} + y_{ht} \right] + \beta \zeta_p E_t [\phi (p - 1)p_{ht+1} + f_{pt+1}] \] (88)
Combining the last three expressions gives a standard forward looking price Phillips curve
\[ \pi_{ht} = \kappa_p (w_t - p_{ht}) + \beta E_t (\pi_{ht+1}) \], (89)
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
\[ i_t = \rho i_{t-1} + (1 - \rho_i)(\psi \pi_t + \psi_y y_{ht}) + \varepsilon_{it} \] (90)
and
\[ i_t^* = \rho i_{t-1}^* + (1 - \rho_i)(\psi \pi_t^* + \psi_y y_{ft}) + \varepsilon_{it}^* \]. (91)

The dynamics of debt (62) can be approximated as
\[ -b_t = -R(i_{t-1} - \pi_t + b_{t-1}) + b_y^{-1}(p_{ht} + y_{ht} - \zeta_H c_t) \], (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 world resource constraint (63) gives
\[ \frac{1}{\zeta_H} (p_{ht} + y_{ht}) + \frac{1}{c_{R,F}} (p_{ft}^* + s_t + y_{ft}) = c_t + \frac{1}{c_{R}} (s_t + c_t^*) \]. (93)

The approximation of equations (64) that link the terms of trade to domestic relative prices is
\[ p_{ht} = -(1 - \alpha) \tau_t \quad \text{and} \quad p_{ft}^* = (1 - \alpha) \tau_t \]. (94)

Finally, the approximation of equation (65) that links real and nominal exchange rates is
\[ s_t = s_{t-1} + e_t - e_{t-1} + \pi_t^* - \pi_t \]. (95)