House Prices, Collateral Effects and Sectoral Output Dynamics in Emerging Market Economies*

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Abstract

This paper studies the channels through which house prices affect sectoral output in emerging market economies, focusing on the role of collateral and borrowing dynamics. We first show that relative to the tradable sector, nontradable sector output is more strongly correlated with house prices and its response to a house price shock in a Panel VAR is larger for a sample of emerging market economies. Then, we study the model dynamics generated by shocks to housing demand in a two-sector small open economy real business cycle model. The results show that housing demand shocks lead to a sectoral reallocation by inducing an expansion in the nontradable sector and a contraction in the tradable sector. The model successfully generates the comovement between the cycle and house prices, matching the strong positive correlation of house prices and nontradable output. We also study the importance of collateral effects for the model dynamics and show that the collateral channel is key to generating the correlations between house prices and sectoral output observed in the data.

JEL classification: E32, E44, F34, F41
Key Words: House Prices, Collateral Effects, Housing Demand Shocks, Sectoral Output

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1 Introduction

The role of house prices in macroeconomic fluctuations has been studied extensively in the literature since the onset of the Great Recession. The effect of house prices on collateral values and borrowing dynamics are at the core of the theoretical models that study housing market fluctuations and business cycles (Iacoviello, 2005; Iacoviello and Neri, 2010; Liu, Wang, and Zha; 2013). These studies, however, mostly focus on advanced economies and house price dynamics in relation to macroeconomic fluctuations have been largely unexplored in the context of emerging market economies. Given the significant prevalence of financial frictions in emerging markets, house price fluctuations are also expected to play an important role in these economies through their effects on borrowing dynamics.

The papers in the literature study the link between house prices and the macroeconomy using closed economy models, not distinguishing between the tradable and nontradable sectors. Hence, they abstract from the link between house prices, real exchange rate and sectoral output dynamics, which are important in an open economy context. On the other hand, the differences in the dynamics of tradable and nontradable output have been established in relation to credit cycles and capital flows in emerging market economies (Tornell and Westermann, 2002; Mendoza and Terrones, 2012). This literature, however, has not explored the effect of house price fluctuations on sectoral output. In this paper, our goal is to bring these two strands of literature together and study the channels through which house prices affect sectoral reallocation and output dynamics in emerging market economies, focusing on the effect of house price changes on collateral values and borrowing.

We begin by documenting the comovement between house prices and sectoral output for a group of emerging market and advanced economies. The data show that house prices in emerging market economies have a strong positive correlation with nontradable output, whereas the house price-tradable output correlation is also positive but weaker. In the advanced economy group, the correlations for the two sectors are still positive but much closer to each other compared to emerging markets. Comparison of the two group of countries provides evidence that there is a stronger pattern in emerging economies regarding the difference in correlations of house prices with the two sectors, underlying the importance of studying the link between house prices and sectoral output in these economies.

To investigate whether house price shocks are the main driver of the pattern observed for emerging market economies, we study the response of tradable and nontradable output to house price shocks using a three-variable panel vector auto regression (PVAR). Impulse response analysis from the PVAR suggests that house price fluctuations generate different dynamics in the two sectors. While a house price shock has a significant and positive effect on the nontradable sector, its effect on the tradable sector is insignificant. Furthermore, the effect on the nontradable sector is larger than that on the tradable sector in all periods, consistent with the stronger relationship between house prices and the nontradable sector observed in the correlations.

We then build a two-sector small open economy real business cycle model to understand the mechanisms that generate these empirical findings. In the model, all agents are credit constrained and use collateral in their borrowing. We generate the house price dynamics through a housing demand shock in the model. We follow the literature and model housing demand shocks as changes in households' preferences for housing (see, for example, Iacoviello, 2005). We calibrate our model to Brazil for the period 1996Q1-2018Q4 and simulate the model using productivity shocks in tradable and nontradable sectors and housing demand shocks.

The impulse response analysis shows that a positive shock to housing demand leads to an expansion in the nontradable sector and total output but not in the tradable sector. A house price increase generates a collateral effect and a wealth effect in the model. Since the amount of borrowing depends on the value of housing, an increase in house prices allows both households and entrepreneurs to borrow more, generating the collateral effect. Additionally, the value of real estate holdings increases, which leads to an increase in wealth. Following a house price increase, these two effects generate an increase in aggregate demand and a real exchange rate appreciation, culminating in a reallocation of labor away from the tradable sector. As a result, the nontradable sector expands and the tradable sector contracts, with the overall effect on total output being positive.

To assess the quantitative importance of the collateral channel for the model dynamics, we use an alternative set up where we shut down the collateral effects by using exogenous credit limits for all agents. Without the collateral effects, the dynamics are generated only by the wealth effect, in which case the response of the economy to a housing demand shock is quite different. As borrowing does not change after the shock, aggregate consumption does not increase as much, which results in a much lower demand for the nontradable good and a depreciation of the real exchange rate. As a result, tradable output expands and the positive response of the nontradable sector to the housing demand shock is much smaller compared to the baseline case. Other than the sectoral output dynamics being different, the responses of the model variables to a housing demand shock are dampened in the absence of an endogenous credit limit. The differences in the magnitudes of the responses for the two cases are quite sizable, showing that the collateral effect serves as an important amplifier in the economy. The amplification effect of collateral constraints observed in our model is in line with the results established in the literature on financial frictions since the seminal works by Kiyotaki and Moore (1997) and Bernanke, Gertler, and Gilchrist (1999) on the role of collateral constraints in amplifying macroeconomics fluctuations.

Since house price changes generate endogenous movements in the amount of borrowing through collateral, we also compare the impulse responses for a housing demand shock with the impulse responses for an exogenous household credit shock. The results show that the effects of a house price increase are very similar to the effects of an exogenous increase in household borrowing. In particular, nontradable sector expands and tradable sector contracts after a positive household credit shock, consistent with the findings of Bahadir and Gumus (2016). The similar effects generated by the two shocks confirm the importance of changes in borrowing induced by the use of collateral in the transmission of house price movements to the economy.

The moment analysis shows that the collateral effect also plays a key role in matching the pattern observed in the data and presented in Table 1 regarding house prices and sectoral output dynamics. The model generates a strong positive correlation between house prices and nontradable output whereas the correlation between house prices and tradable output is also positive but much weaker, consistent with the data. When the collateral effects are shut down by assuming exogenous credit limits, house prices are more strongly correlated with tradable output than with nontradable output. Hence, the correlations between house prices and sectoral output are reversed, showing that the collateral channel is critical in matching the patterns observed in the data.

We also investigate the role of borrowing constraints in generating the comovement between house prices and sectoral output observed in the data. When we study a case in which households are unconstrained in their borrowing, the model generates house price-sectoral output correlations that are inconsistent with the data, especially for the nontradable sector. The model's performance deteriorates in other important dimensions as well, including consumption volatility and net export-output correlations. These results underline the importance of borrowing constraints for studying emerging market business cycles.

Our paper is related to the literature that studies the effect of credit cycles, capital flows and sudden stops on sectoral output and real exchange rate dynamics in emerging markets (Tornell and Westermann, 2002; Schneider and Tornell, 2004; Kehoe and Ruhl, 2008; Mendoza and Terrones, 2012; Bahadir and Gumus, 2016). In this literature, an increase in capital inflows or an expansion in private sector credit triggers an expansion in aggregate demand and starts a mechanism that leads to a reallocation of resources from the tradable sector to the nontradable sector together with a real exchange rate appreciation. Sudden stops have the opposite effect on sectoral output and are associated with a relatively larger contraction in the nontradable sector. Our paper contributes to this literature by introducing another mechanism that generates a sectoral reallocation, which results from changes in house prices and borrowing.

An extensive empirical literature that has developed since the Great Recession studies the effects of house price movements on the economy. In this literature house prices have been analyzed in relation to borrowing and consumption dynamics (Mian and Sufi, 2011, 2015; Mian, Rao, and Sufi, 2013; Kaplan, Mitman, and Violante, 2020), as well as employment (Mian and Sufi, 2014; Adelino, Schoar, and Severino, 2018) and investment (Chaney, Sraer, and Thesmar, 2012). Within this literature, the findings of Mian and Sufi (2014), who study the effect of house prices on the decline in US employment between 2007 and 2009, are particularly relevant for our paper. Using county-level employment data, they show that the counties with a larger decline in the housing net worth of households experience a larger decline in nontradable employment whereas there is no effect on tradable employment. They argue that the decline in spending caused by wealth and collateral effects of lower housing net worth leads to a decline in nontradable employment since this sector heavily relies on local demand. Our paper provides a theoretical framework to study these linkages between house prices and sectoral output and to quantify the relative importance of wealth and collateral effects. Our findings emphasize the importance of the collateral channel in emerging market economies, which is consistent with the fact that these countries face tighter constraints in financial markets, increasing the effect of collateral values on borrowing dynamics.

Our work also belongs to the extensive literature that incorporates housing and collateral constraints into dynamic stochastic general equilibrium models including Iacoviello, 2005; Iacoviello and Neri, 2010; Liu, Wang, and Zha; 2013 among others. These papers study the effects of collateral constraints using closed economy models and do not explore the link between house prices, real exchange rate fluctuations and sectoral output dynamics. We contribute to this literature by studying the interaction between house prices and borrowing in an open economy setting, focusing on the distinction between the tradable and nontradable sectors.

Understanding the effects of house price fluctuations on sectoral output dynamics also has important implications from a policy-making perspective. Our results show that an increase in house prices leads to a reallocation of resources from the tradable to the nontradable sector through changes in the real exchange rate. This shift in resources benefits the nontradable sector at the expense of the more productive tradable sector, which may affect the international competitiveness of the economy. The correlations between house prices and sectoral output documented in this paper adds another layer of factors to be considered when policy makers are evaluating the consequences of a booming housing market.

2 Empirical Evidence

2.1 Sectoral Output and House Price Correlations

In this section, we document the relationship between house prices and sectoral output for a group of emerging and advanced economies. In Table 1, the first panel presents the correlations of real house prices with total, tradable and nontradable output for emerging market economies and the second panel shows the same set of correlations for advanced economies. The sample consists of nine emerging market economies that have at least 60 quarters of house price and sectoral output data and Group of Seven (G-7) countries. The choice of G-7 countries is motivated by the fact that the existing literature on house prices and business cycles mostly focuses on the US economy and using this group allows us to show the correlation patterns for the US and other similar advanced economies.

The evidence from the first panel shows that there is a high positive correlation between aggregate output and house prices in emerging market economies, with an average correlation of 0.47. The correlations also reveal a clear pattern regarding the relationship between sectoral output and house prices in emerging market economies. Nontradable output has a strong positive correlation with house prices, exceeding the correlation of tradable output in all countries except for Bulgaria. The average correlation between house prices and the nontradable sector output is 0.48 and for several countries this correlation is higher than 0.60. The strength of the relationship between house prices and the tradable sector output is much weaker, however, with an average correlation of 0.30 for the nine economies in our sample. These differences in correlations suggest that the two sectors exhibit different patterns with respect to the strength of their relationship with house prices.[1]

It is possible that an increase in house prices raises economic activity in the nontradable sector directly through higher construction. To explore the role of construction in generating the correlations observed in the data, we exclude construction from nontradable output and recompute the correlations. In this case, the average correlation between house prices and the nontradable sector becomes 0.43, which shows that the construction sector plays a relatively minor role in the correlations between nontradable output and house prices.

In the second panel, we present the house price-sectoral output correlations for the G-7 countries. The correlations of house prices with the two sectors are much closer to each other for this group, with the average correlation equal to 0.40 for the nontradable sector and 0.35 for the tradable sector. Relative to emerging markets, we observe a more mixed pattern for these economies, with some countries having quite low house price-sectoral output correlations such as Germany and Italy. Overall these numbers suggest that the

[1] Figure 5 in the Appendix plots house prices and sectoral output for the countries presented in the first panel.

comovement between sectoral output and house prices in advanced economies do not exhibit large differences as in emerging markets.

Table 1. House price and sectoral output correlations

	Correlation of house prices with		
	Total output	Tradable output	Nontradable output
Emerging economies			
Brazil	0.51	0.22	0.68
Bulgaria	0.89	0.65	0.49
Croatia	0.69	0.42	0.72
Korea	0.41	0.16	0.63
Lithuania	0.81	0.64	0.81
Mexico	0.11	0.04	0.24
Peru	0.13	0.15	0.17
South Africa	0.42	0.29	0.31
Thailand	0.24	0.12	0.27
Average	0.47	0.30	0.48
Median	0.42	0.22	0.49
Advanced economies			
Canada	0.21	0.28	0.16
France	0.63	0.56	0.62
Germany	0.03	-0.05	0.12
Italy	0.18	0.15	0.19
Japan	0.61	0.59	0.58
UK	0.63	0.50	0.62
USA	0.50	0.45	0.51
Average	0.40	0.35	0.40
Median	0.37	0.45	0.37

Note: Tradable output includes manufacturing and agriculture, forestry and fishing; nontradable output includes services and construction. House prices are real residential property prices. The statistics are calculated with quarterly data. All series are in logs, seasonally adjusted and HP filtered. See the appendix for the data sources.

2.2 Panel VAR Evidence on Emerging Market Economies

In the section above, we show that nontradable sector has a stronger comovement with house prices compared to tradable sector in the emerging economy group. Since these correlations can result from a number of different factors, here we conduct a PVAR analysis to investigate whether house price shocks are the main driver of the pattern observed in emerging market economies.

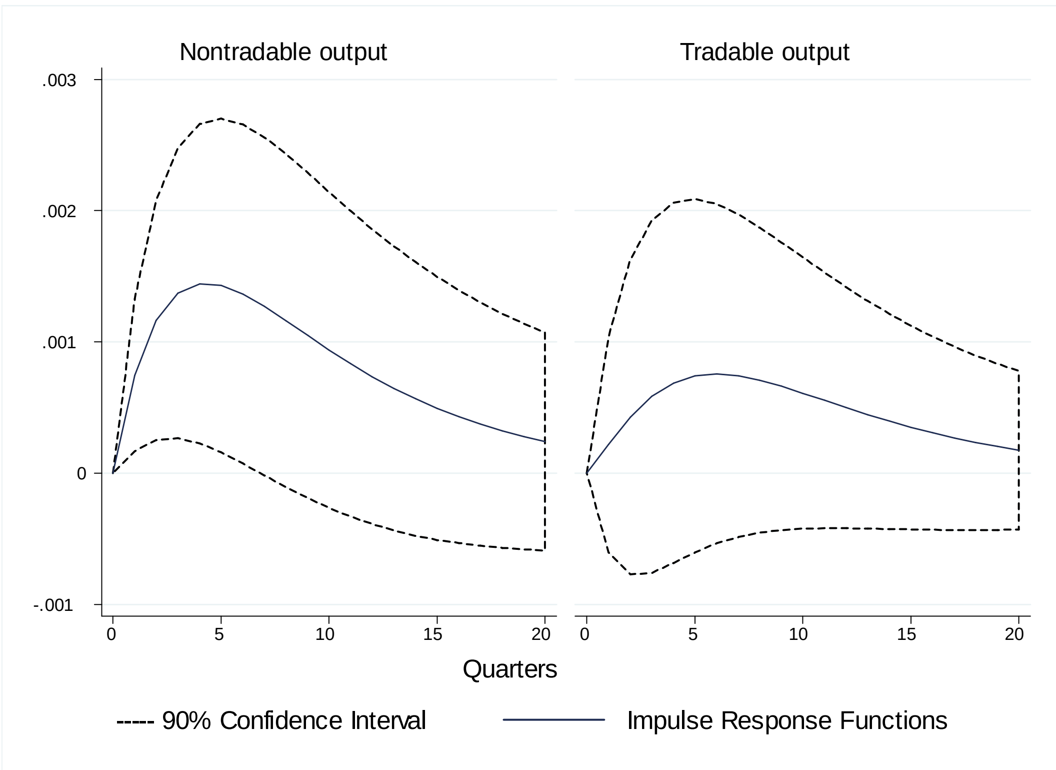

Figure 1. Impulse responses to a house price shock

Figure 1 presents impulse responses (with 90-percent monte-carlo confidence bands) from the PVAR with tradable sector output, nontradable sector output, and house prices for the same sample used in Table 1. The PVAR includes the first lag of each variable based on the Hannan-Quinn criterion. We identify the structural shocks through Cholesky decomposition, with the detrended tradable output first, followed by detrended nontradable output, and house prices.[2] The results from the PVAR suggest that house price shocks generate a stronger positive response of nontradable output compared to tradable output.

[2] The ordering of the variables does not affect the results.

While the peak response of nontradable output to a house price shock is 0.14 percent, the peak response of tradable output is only 0.076 percent, and the response of nontradable output is larger in all periods after the shock. More importantly, the effect of the house price shock on nontradable output is significant whereas the effect on tradable output is insignificant. These results suggest that house price shocks generate different sectoral output dynamics and play an important role in understanding the patterns we observe with respect to the correlations. In the model presented below, we study the mechanisms that generate these results.

3 The Model

We use a two-sector small open economy model with tradable and nontradable goods. Our model is similar to that of Bahadir and Gumus (2016) with the addition of housing. There are three types of agents in the model: households and entrepreneurs in the tradable and nontradable sectors. Both sectors use capital, labor and real estate for production. Households provide labor services while capital is held by entrepreneurs. There is a fixed stock of real estate, which is used by all agents as households get utility from housing services and entrepreneurs use real estate in production. While all agents have access to international financial markets, they face constraints on their borrowing and use real estate as collateral. The only asset traded in international financial markets is a non-contingent real bond.

3.1 Households

Households choose consumption, labor and housing services to maximize their expected lifetime utility given by

$$E_0 \sum_{t=0}^{\infty} (\beta^h)^t \left[\ln \left(c_t^h(c_{t,N}^h, c_{t,T}^h) \right) + \gamma_t \ln \left(h_t^h \right) - \psi l_t^\eta \right], \quad \eta > 1, \psi > 0, \tag{1}$$

where $\beta^h \in (0,1)$ is the discount factor of the household, c_t^h is the consumption aggregator, h_t^h is household's holdings of housing, l_t represents labor, η is the parameter that governs the intertemporal elasticity of substitution in labor supply and ψ is the measure of disutility from working. Consumption is an aggregate of the consumption of nontradable goods, $c_{t,N}^h$, and the consumption of tradable goods, $c_{t,T}^h$. Households' utility from housing is affected by a preference shock, γ_t.

The budget constraint of households is given by

$$c_{t,T}^h + p_{t,N}c_{t,N}^h + R_{t-1}b_{t-1}^h + q_{h,t}(h_t^h - h_{t-1}^h) = w_{t,T}l_{t,T} + p_{t,N}w_{t,N}l_{t,N} + b_t^h, \tag{2}$$

where b_t^h denotes the amount borrowed by the household at time t, R_{t-1} is the gross interest rate, $q_{h,t}$ is the housing price, $l_{t,T}$ and $l_{t,N}$ denote labor supplied to tradable and nontradable sectors, respectively, $w_{t,T}$ and $w_{t,N}$ denote the wage rates in the two sectors and $p_{t,N}$ is the relative price of the nontradable good, where the price of the tradable good is normalized to one. In the solution of the model, we take the interest rate as constant so that $R_t = R$, for all t.

Households face a borrowing constraint in every period. The total value of their debt including both interest and principal is constrained by a fraction, m^h, of the expected value of their housing stock next period. The borrowing constraint of households is of the form

$$R_t b_t^h \leq m^h E_t \left(q_{h,t+1} h_t^h \right). \tag{3}$$

We assume that $\beta^h < 1/R$, which guarantees that the borrowing constraint is binding in and around the steady state.

3.2 Entrepreneurs

We present the entrepreneur's problem for both the tradable and the nontradable sectors in this section. In the rest of the section, we use j to specify the sectors, where $j = T$ denotes the tradable sector and $j = N$ denotes the nontradable sector.

Entrepreneurs produce output by a Cobb-Douglas technology using capital, real estate and households' labor services:

$$y_{t,j} = e^{A_{t,j}} k_{t-1,j}^{\alpha_j} (h_{t-1,j}^e)^{\mu_j} l_{t,j}^{1-\alpha_j-\mu_j}, \tag{4}$$

where $k_{t-1,j}$ and $h^e_{t-1,j}$ denote entrepreneur's capital and real estate holdings, respectively, in sector j at the start of period t and $A_{t,j}$ is an exogenous stochastic productivity shock in sector j.

The capital accumulation decision is made by the entrepreneurs and the equation for capital accumulation is given by

$$i_{t,j} = k_{t,j} - (1-\delta)k_{t-1,j}, \tag{5}$$

where $i_{t,j}$ denotes investment in sector j. The investment good used in both sectors is assumed to be tradable and δ is the common depreciation rate.

Firms in both sectors have to pay a fraction of the wages before output becomes available and they need working capital loans from foreign lenders. Thus, tradable sector firms (nontradable sector firms) borrow $\theta w_{t,T} l_{t,T}$ $(\theta p_{t,N} w_{t,N} l_{t,N})$ at the beginning of period t and repay $R_t \theta w_{t,T} l_{t,T}$ $(R_t \theta p_{t,N} w_{t,N} l_{t,N})$ at the end of the period as in Neumeyer and Perri (2005). As households, entrepreneurs also face a borrowing constraint due to enforceability problems. Following Mendoza (2010) and Bahadir and Gumus (2016), we assume that the entrepreneur's total debt, which includes intertemporal debt, b^{ej}_t, and within-period working capital loans, cannot exceed a fraction of the expected value of their collateral assets, which are capital holdings and real estate.

In the case of the tradable sector, the borrowing constraint takes the form

$$R_t b^{eT}_t + R_t \theta w_{t,T} l_{t,T} \leq m^{eT} E_t (q_{k,t+1,T} k_{t,T} + q_{h,t+1} h^e_{t,T}). \tag{6}$$

In the case of the nontradable sector, the borrowing constraint takes the form

$$R_t b^{eN}_t + R_t \theta p_{t,N} w_{t,N} l_{t,N} \leq m^{eN} E_t (q_{k,t+1,N} k_{t,N} + q_{h,t+1} h^e_{t,N}). \tag{7}$$

The loan-to-value (LTV) ratios are denoted by m^{ej} and $q_{k,t+1,j}$ is the price of capital at time $t+1$. We use adjustment costs for capital accumulation to reduce the volatility of investment. Therefore, the price of capital in terms of tradable consumption differs from one and is given by

$$q_{k,t,j} = 1 + \frac{\partial \Phi(k_{t-1,j}, i_{t,j})}{\partial i_{t,j}}, \tag{8}$$

where $\Phi(k_{t-1,j}, i_{t,j})$ is the capital adjustment cost function.[3]

The entrepreneur's problem is to maximize her expected utility

$$E_0 \sum_{t=0}^{\infty} (\beta^{ej})^t \ln \left(c_t^{ej}(c_{t,N}^{ej}, c_{t,T}^{ej}) \right) \tag{9}$$

subject to technology, borrowing and flow of funds constraints. The flow of funds constraint for the tradable sector is

$$c_{t,T}^{eT} + p_{t,N} c_{t,N}^{eT} + w_{t,T} l_{t,T} + i_{t,T} + \Phi(k_{t-1,T}, i_{t,T}) + q_{h,t}(h_{t,T}^e - h_{t-1,T}^e) + R_{t-1} b_{t-1}^{eT} + (R_t - 1)\theta w_{t,T} l_{t,T} = y_{t,T} + b_t^{eT}, \tag{10}$$

and the flow of funds constraint for the nontradable sector is

$$\begin{aligned} c_{t,T}^{eN} + p_{t,N} c_{t,N}^{eN} + p_{t,N} w_{t,N} l_{t,N} + i_{t,N} + \Phi(k_{t-1,N}, i_{t,N}) + q_{h,t}(h_{t,N}^e - h_{t-1,N}^e) \\ + R_{t-1} b_{t-1}^{eN} + (R_t - 1)\theta p_{t,N} w_{t,N} l_{t,N} = p_{t,N} y_{t.N} + b_t^{eN}. \end{aligned} \tag{11}$$

As in the case of households, consumption of the entrepreneurs, c_t^{ej}, is an aggregate of the consumption of nontradable and tradable goods, $c_{t,N}^{ej}$ and $c_{t,T}^{ej}$, respectively.

Similar to the household's discount factor, we assume that $\beta^{ej} < 1/R$ so that the borrowing constraints are binding in and around the steady state.

3.3 Equilibrium

Given initial conditions b_0^h, b_0^{eT}, b_0^{eN}, $k_{0,T}$, $k_{0,N}$, h_0^h, $h_{0,T}^e$, $h_{0,N}^e$, a constant real interest rate R, the sequence of shocks to sectoral productivity levels and housing demand of households, the competitive equilibrium is defined as a set of allocations and prices $\{y_{t,T}, y_{t,N}, l_{t,T}, l_{t,N}, k_{t,T}, k_{t,N}, i_{t,T}, i_{t,N}, h_t^h, h_{t,T}^e, h_{t,N}^e, c_t^h, c_{t,T}^h, c_{t,N}^h, c_t^{eT}, c_{t,T}^{eT}, c_{t,N}^{eT}, c_t^{eN}, c_{t,T}^{eN}, c_{t,N}^{eN}, b_t^h, b_t^{eT}, b_t^{eN}, p_{t,N}, w_{t,T}, w_{t,N}, q_{k,t,T}, q_{k,t,N}, q_{h,t}\}$ such that (i) the allocations solve the problems of the household and the entrepreneurs in the tradable and nontradable sectors at the equilibrium prices, (ii) factor markets clear, (iii) the price of capital is given by $q_{k,t,j} = 1 + \frac{\partial \Phi(k_{t-1,j}, i_{t,j})}{\partial i_{t,j}}$ for $j = T, N$ and

[3] The price of capital is derived from the firm's optimization problem. It is equal to the Lagrange multiplier of the capital accumulation equation divided by the Lagrange multiplier of the budget constraint, i.e. the marginal value of capital measured in tradable consumption units.

(iv) the resource constraints for the tradable and nontradable sectors hold:

$$c^h_{t,T} + c^{eT}_{t,T} + c^{eN}_{t,T} + i_{t,T} + i_{t,N} + \Phi(k_{t-1,T}, i_{t,T}) + \Phi(k_{t-1,N}, i_{t,N}) + nx_t = y_{t,T} \tag{12}$$

$$c^h_{t,N} + c^{eT}_{t,N} + c^{eN}_{t,N} = y_{t,N} \tag{13}$$

where the net exports is defined as

$$nx_t = R_{t-1}\left(b^h_{t-1} + b^{eT}_{t-1} + b^{eN}_{t-1}\right) + (R_t - 1)\theta w_{t,T} l_{t,T} + (R_t - 1)\theta p_{t,N} w_{t,N} l_{t,N} - \left(b^h_t + b^{eT}_t + b^{eN}_t\right). \tag{14}$$

We assume that the total stock of real estate is fixed. The market clearing condition for the real estate market is

$$h^h_t + h^{eT}_t + h^{eN}_t = H, \tag{15}$$

where H denotes the fixed stock of real estate.

4 Calibration

The model is solved using quarterly data from Brazil for the period 1996Q1-2018Q4. The construction of the series used in the model solution is explained in detail in the Appendix. The parameter values of the model are summarized in Table 2.

The discount factors are set such that the borrowing constraints remain binding in the solution of the model. The values for β^{eT} and β^{eN} are set to 0.92, and the value for β^h is set to 0.93. The gross real interest rate, R, is set to 1.0125 to match the average real interest rate in Brazil. The real interest rate is calculated as the sum of the US real interest rate and the risk premium for Brazil measured by J.P. Morgan's Emerging Markets Bond Index Global (EMBIG).

The values of the LTV ratios, m^h, m^{eN} and m^{eT}, are set to match the average value of the credit-to-GDP ratio for each type of credit. For household credit, we use total credit to households from the Bank for International Settlements (BIS) for the 1996-2018 period. BIS dataset only reports total business credit, hence we use the Central Bank of Brazil's outstanding credit by economic activity data series to construct sectoral credit data. The required sectoral series start from 2012, which forces us to use a shorter time period for the sectoral credit ratios. The averages of the credit-to-GDP ratios are 17.99% for household credit, 11.65% for nontradable sector credit and 12.60% for tradable sector credit.[4]

Table 2. Parameter values of the benchmark model

Parameter	Value	Description	
β^h	0.93	Discount factor of households	
β^{eN}	0.92	Discount factor of nontradable sector entrepreneurs	
β^{eT}	0.92	Discount factor of tradable sector entrepreneurs	
R	1.0125	Real interest rate	
η	2.2048	Labor curvature	
ψ	15.989	Labor weight in utility	
$\bar{\gamma}$	0.3754	Housing weight in utility	
ω	0.55	Nontradable weight in the consumption aggregator	
δ	0.08	Annual depreciation rate	
α_T	0.23	Capital exponent in tradable production	
μ_T	0.14	Real estate exponent in tradable production	
α_N	0.13	Capital exponent in nontradable production	
μ_N	0.19	Real estate exponent in nontradable production	
θ	0.25	Working capital coefficient	
ϕ	25.56	Capital adjustment cost coefficient	
m^h	0.1822	Loan-to-value ratio for the household	
m^{eN}	0.2377	Loan-to-value ratio in the nontradable sector	
m^{eT}	0.2313	Loan-to-value ratio in the tradable sector	
Stochastic processes			
ρ^{A_T}	0.47	$\sigma(\varepsilon^{A_T})$	0.02156
ρ^{A_N}	0.73	$\sigma(\varepsilon^{A_N})$	0.00694
ρ^{γ}	0.95	$\sigma(\varepsilon^{\gamma})$	0.04329

[4]Central Bank of Brazil provides a different set of data on sectoral credit that goes back further. However, these series are discontinued and end at 2014. When we compute the averages using these data, we get very similar averages for tradable and nontradable sector credit.

Calibrating the shares of input in the production functions of the two sectors requires data on factor income shares at the sectoral level for labor, capital and real estate. Since there is no such detailed data for Brazil, we use the values calculated by Valentinyi and Herrendorf (2008) for the US economy. They measure the income share of equipment as 0.23 and income share of land and structures as 0.14 for the tradable sector. The income shares for the nontradable sector are 0.13 for equipment and 0.19 for land and structures. These values are in line with the conjecture that the tradable sector is more capital intensive whereas nontradable sector uses real estate more intensively.

The value of η is set such that the intertemporal elasticity of substitution in labor supply, $1/(\eta-1)$, equals 0.83 as in Kose (2002). The annual depreciation rate is set to 0.08 following Meza and Quintin (2007). The value of ψ is set to 15.989 to match an average time spent working of 20% of total time as in Neumeyer and Perri (2005). We set the working capital coefficient, θ, equal to 0.25 following Bahadir and Gumus (2016) who use 0.25 for Turkey and Mendoza (2010) who uses 0.26 for Mexico.

The consumption aggregator is assumed to be of the Cobb-Douglas form for all agents:

$$c_t^s\left(c_{t,N}^s, c_{t,T}^s\right) = (c_{t,N}^s)^{\omega}(c_{t,T}^s)^{1-\omega}, \quad 0<\omega<1, \quad \text{for } s = h, eT, eN. \tag{16}$$

Following Devereux et al (2006), we set the share of nontradable goods in the consumption aggregator, ω, equal to 0.55.

The form of the capital adjustment cost functions is given by

$$\Phi(k_{t-1,j}, i_{t,j}) = \frac{\phi_j}{2} k_{t-1,j}\left(\frac{i_{t,j}}{k_{t-1,j}} - \delta\right)^2, \qquad \text{for } j = T, N. \tag{17}$$

Since sectoral investment data are not available for Brazil at the quarterly frequency, we cannot set the parameters that determine the size of the adjustment costs, ϕ_j, separately to match the volatility of investment in the two sectors. Therefore, we use the same value for both sectors and set it to match the volatility of aggregate investment in units of tradables relative to tradable output in the data.[5]

[5] Since investment is in units of tradables in the model, we convert the aggregate investment series from the data to tradable units. For this purpose, we divide the nominal investment series with the GDP deflator for the tradable sector, which is calculated by dividing the nominal values for the tradable sector output with the real values.

The stochastic processes used in the model are for total factor productivity in the two sectors and the housing demand shock. The processes for the productivity shocks are estimated using the Solow residuals for the tradable and nontradable sectors in Brazil as

$$A_{t,j} = \rho^{A_j} A_{t-1,j} + \varepsilon_t^{A_j}, \tag{18}$$

where $j = T, N$ and $\varepsilon_t^{A_j}$ are normally distributed and serially uncorrelated.

The stochastic process for housing demand is assumed to be of the following form:

$$\gamma = \bar{\gamma} \exp(\tilde{\gamma}_t), \tag{19}$$

where

$$\tilde{\gamma}_t = \rho^{\gamma} \tilde{\gamma}_{t-1} + \varepsilon_t^{\gamma}, \tag{20}$$

where ε_t^{γ} is normally distributed and serially uncorrelated. The standard deviation of ε_t^{γ} is set to match the volatility of the house price series from the data and ρ^{γ} is set to 0.95, a value that is within the range of numbers used in the literature to achieve high persistence in house prices.

The value of $\bar{\gamma}$ determines the steady-state value of residential housing in the model. Since there is no data on real estate stock in Brazil, we set the value of $\bar{\gamma}$ such that the steady-state value of residential housing as a ratio of annual output equals 100% and analyze the implications of changing this value in the robustness analysis. The values used for the factor income shares of real estate μ_T and μ_N given in Table 2 imply that the steady-state commercial real estate-to-annual output ratios are 24.13% and 32.34% for tradable sector and nontradable sector, respectively. We again analyze the implications of changing the factor income shares in terms of model predictions in the robustness analysis.

5 Results

5.1 Impulse Response Analysis

Figure 2 shows the response of the economy to a positive one percent shock to household's utility from housing services, i.e. an increase in γ. With an increase in household's demand for housing, house price increases, which affects the model dynamics through two different channels. Since all agents use real estate as collateral, the house price increase raises the value of their collateral assets and leads to higher borrowing, generating a collateral effect. Even though the firms reduce their real estate holdings by selling them to the household, the house price increase is sufficiently large to generate an expansion in the value of collateral held by firms. Hence, for all agents, there is an increase in borrowing on impact as seen in the figure. The other channel works through changes in the housing wealth of agents. With the house price increase, the value of real estate holdings increases, inducing a wealth effect.

The combination of the collateral and wealth effects generates an increase in aggregate demand, which affects the sectoral output dynamics and leads to an expansion in the nontradable sector and a contraction in the tradable sector. With higher demand for the nontradable good, the real exchange rate appreciates. Since the return to labor increases in the nontradable sector with the appreciation of the real exchange rate, labor moves from the tradable sector to the nontradable sector. As a result, the nontradable sector expands and the tradable sector contracts. With the production of the nontradable good and its price increasing, total output measured in units of the tradable good increases as well.

As a result of increased borrowing and wealth due to higher house prices, all agents increase their consumption and total consumption expands.[6] Additionally, investment in both sectors increase. Firms are able to borrow more through higher collateral values due to the increase in real estate prices. They also generate additional revenues by selling some of their real estate to the households. With the additional funds available through these two channels, they increase their investment. Even though the shock originates in the household sector, it affects the firms through higher real estate values and leads to higher investment. This effect is similar to the mechanism discussed in Bahadir and Gumus (forthcoming), where real estate serves as a common asset for households and entrepreneurs and generates a transmission of shocks between these agents. It is also in line with the findings of Liu et al. (2013) on the role of land as a collateral asset in firms' credit constraints in generating the comovement between land prices and business investment observed in the US.

[6] The impulse responses for the separate consumption levels show that all agents increase their consumption. In the figure, we only show total consumption in order to save space.

Overall, a positive housing demand shock raises the price of housing, which leads to a sectoral reallocation in the economy with the nontradable sector expanding and the tradable sector contracting. At the same time, it leads to an increase in total production, total consumption and sectoral investment levels.

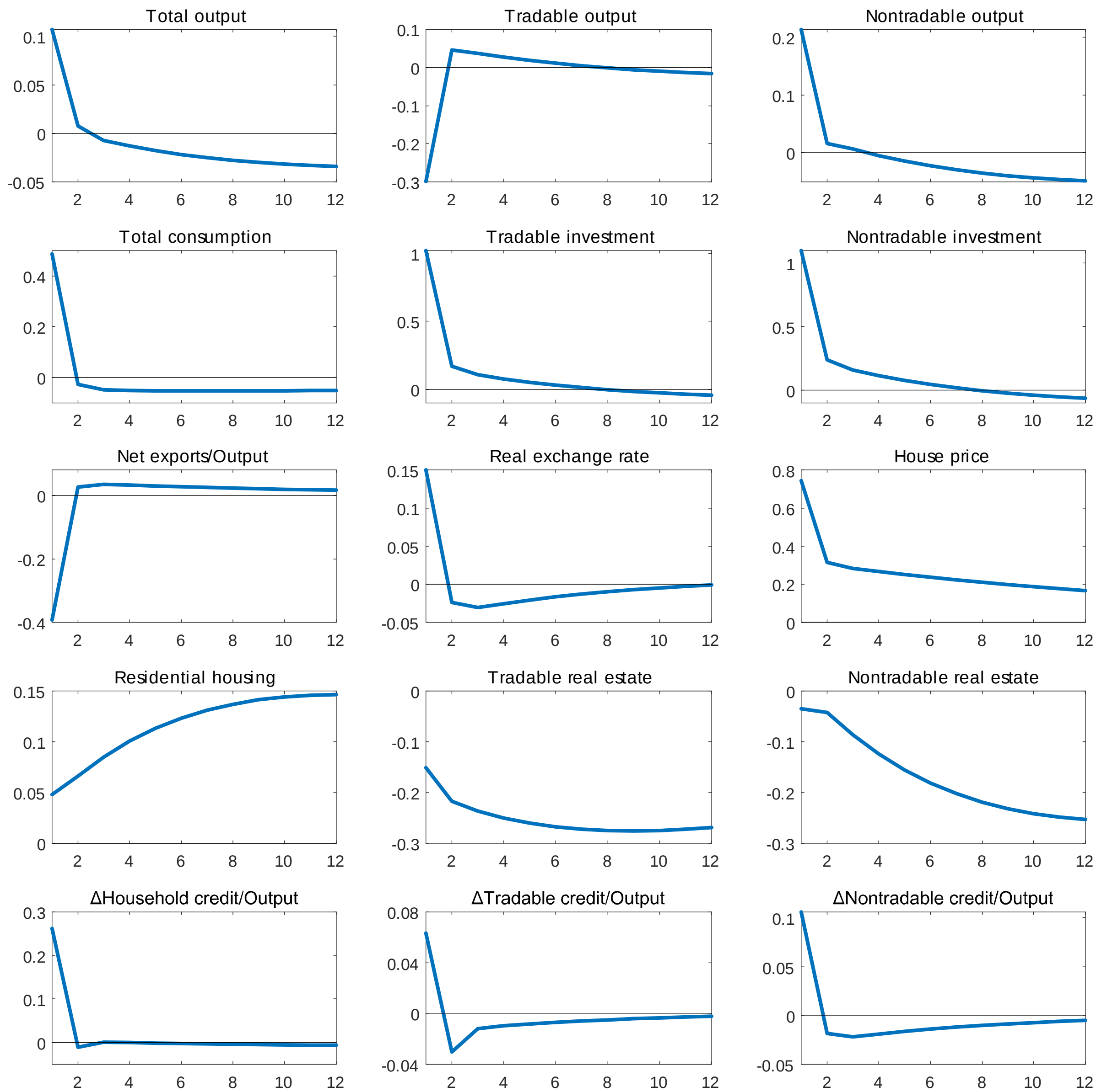

Figure 2. Positive shock to housing demand: Percent deviation of variables from their steady-state values in the benchmark model

The impulse responses generated from the model are in line with the PVAR evidence we present in Section 2.2. As in the model, our data analysis shows that an increase in house prices has a positive effect on nontradable output. This effect is statistically significant, providing empirical support for the key relationship of the model. The results from the PVAR analysis also shows that, while still positive, the response of tradable output to an increase in house prices is smaller compared to that of nontradable output and not statistically different from zero. While empirically we do not observe a contraction in the tradable output after an increase in house prices as in the model, we find that house price shocks have stronger effects on nontradable output relative to tradable output, consistent with our model's predictions.

To better understand the role of collateral in the model dynamics, we compare the impulse responses to a positive housing demand shock for the benchmark model with the impulse responses for a case without collateral in Figure 3. Specifically, in the alternative model without collateral, the agents do not use any collateral in borrowing and the amount of borrowing is assumed to be constant for each agent, equaling the respective credit limit, m^i for $i = h, eN$ and eT. We adjust the values of the credit limits so that the credit-to-output ratio for each agent remains the same as in the benchmark model.

The comparison of the impulse responses of the two cases shows that the dynamics in the benchmark model are to a large extent driven by the collateral effect. In the benchmark model, the increase in the real estate values enables the agents to borrow more in addition to the wealth effect generated by higher housing values. In the alternative model, changes in the value of housing only generate a wealth effect. The impulse responses show that the housing demand shock affects the tradable and nontradable sectors differently when there is no collateral effect. In the no-collateral case, aggregate consumption increases by a very small amount. This is due to household consumption decreasing while entrepreneurs' consumption still increases. Without any additional resources available through higher borrowing, households reduce their consumption to purchase real estate after a housing demand shock. This results in a lower demand for the nontradable good and a depreciation of the real exchange rate, which reverses the reallocation of labor between the two sectors. As a result, tradable output expands in this case compared to the contraction in the benchmark model and the nontradable sector expands by a much smaller amount.

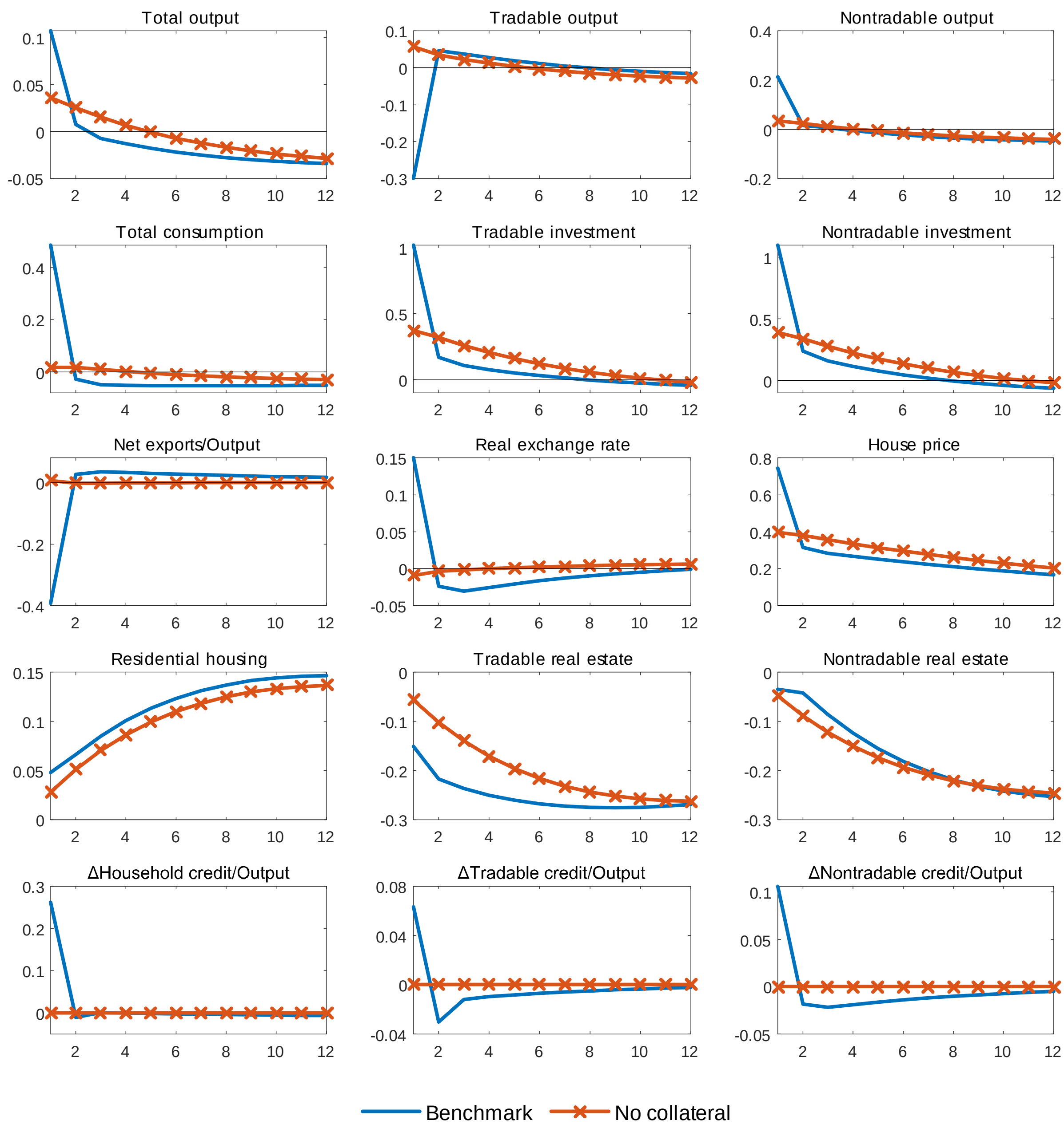

Figure 3. Positive shock to housing demand: Percent deviation of variables from their steady-state values in the benchmark model vs. the model with no collateral effect

Other than the differences observed in the behavior of sectoral output and the real exchange rate, the responses are in the same direction as the benchmark model but smaller for most variables. The smaller responses show that the collateral effect serves as an amplifier in the economy, which is consistent with the results we present in the moment analysis in Section 4.2. Furthermore, comparing the magnitudes of the responses for the two cases show that the collateral effect is quite sizable. For instance, it accounts for 84%

of the response for nontradable output, about 65% for total output and sectoral investment levels and 47% for house price. These results show that the collateral effect is stronger than the wealth effect for most variables, explaining a significant fraction of the responses.

The impulse response analysis shows that the dynamics driven by house prices following a housing demand shock are mostly generated through the collateral effect. Without the collateral effect, the variables respond much less and sectoral output dynamics are quite different. By enabling a higher level of borrowing following a house price increase, the use of collateral leads to an endogenous expansion in the borrowing capacity of the agents. While borrowing responds endogenously in this model, the effects of shocks that exogenously change the borrowing limits have been analyzed in different contexts in the literature (Jermann and Quadrini, 2012; Khan and Thomas, 2013; Bahadir and Gumus, 2016; Perri and Quadrini, 2018). Bahadir and Gumus (2016) show that a household credit expansion leads to a sectoral reallocation and real exchange rate appreciation, as in our analysis, using a two-sector small open economy model without housing. To understand how the effects of an exogenous borrowing increase compare with the effects of the borrowing increase induced by the use of collateral in our model, we compare the impulse responses of the housing demand shock with the impulse responses of a household credit shock, i.e. a shock to m^h, in Figure 6 in the appendix.[7] The results show that the dynamics generated by the two shocks are very similar. With a household credit expansion, housing demand increases, raising the price of housing. Both the exogenous increase in the borrowing capacity and the ensuing increase in borrowing due to higher collateral values raise aggregate demand, generating a real appreciation and an expansion in the nontradable sector, as in our analysis. The similar effects generated by the two shocks show the importance of the endogenous borrowing increase enabled by the use of collateral in borrowing. Through the value of collateral, an increase in housing demand sets into motion a mechanism that raises the borrowing capacity of the economy much like a credit shock.

It is worth mentioning that most of the impulse responses in the benchmark model have a kink and a decline in the size of the response in the period after the shock, which is caused

[7] For the household credit shock, the loan-to value ratio of the household is assumed to be characterized by $m_t^h = m^h \exp(\tilde{m}_t^h)$, where $\tilde{m}_t^h$ follows an AR(1) process $\tilde{m}_t^h = \rho^h \tilde{m}_{t-1}^h + \varepsilon_t^h$,and the innovations ε_t^h are normally distributed and serially uncorrelated. The impulse responses are generated using a one percent shock and ρ^h is set to 0.95 as in the housing demand shock.

by the borrowing dynamics. The house price increase leads to an increase in borrowing in the initial period and the amount of new debt gradually declines every period as collateral values decline following the shock. The increase in borrowing in the initial period leads to a sizable response in all of the variables. However, since the amount borrowed in the first period needs to be repaid with interest in the next period and debt payment including interest exceeds the amount of new debt available due to the decline in collateral values, the responses observed in the initial period quickly diminish in the second period. The impulse responses in the alternative model without the collateral effects shown in Figure 3 do not have any kinks and exhibit smooth convergence to the steady state, showing that the borrowing dynamics cause the kinks observed in the benchmark model.

5.2 Moment Analysis

In this section, we examine the ability of the model to match the main characteristics of business cycles observed in Brazil in the period 1996Q1-2018Q4. Table 3 documents the key business cycle moments obtained from the data and the model. The model is log-linearized around the steady state and the moments are calculated using HP-filtered series. Total output, consumption and investment series used in the calculation of the data moments are converted to tradable units to make them consistent with their model counterparts.[8] The model dynamics are generated by sectoral productivity shocks and the housing demand shock.

The moments generated by the model are mostly consistent with the moments observed in the data. In particular, the correlations of house price with sectoral output are very close to the data. The model generates a much stronger correlation between house price and nontradable output compared to tradable output, which is in line with the empirical regularity observed in emerging economies as documented in Table 1. As illustrated in the impulse response analysis, when house prices increase, the combined effect of higher collateral values and a housing wealth increase creates an increase in aggregate demand. This

[8] To obtain the series measured in tradable units, the nominal series are divided by the GDP deflator for the tradable sector, which is calculated by dividing the nominal values for the tradable sector output with the real values.

leads to a real exchange rate appreciation and higher nontradable production, generating the close correlation between house prices and nontradable output.

Table 3. Business cycle moments

	Data	Model	No collateral	Unconstrained household	No housing demand shock
$\sigma(Y)$	4.60	2.40	2.22	2.04	2.34
$\sigma(YT)$	3.04	2.39	2.52	3.97	2.05
$\sigma(YN)$	1.21	1.28	0.83	0.99	0.86
$\sigma(C)/\sigma(Y)$	0.98	1.45	0.90	0.21	1.15
$\sigma(I)/\sigma(YT)$	2.52	2.52	1.67	0.38	2.01
$\sigma\left(\frac{NX}{Y}\right)$	0.86	1.80	0.39	1.75	0.58
$\sigma(RER)$	8.95	1.56	1.19	0.64	1.37
$\sigma(q_h)$	3.74	3.74	2.96	0.96	2.19
$\rho(C,Y)$	0.96	0.89	0.98	0.61	0.99
$\rho(I,Y)$	0.90	0.81	0.89	0.66	0.98
$\rho\left(\frac{NX}{Y},Y\right)$	-0.47	-0.41	0.49	0.98	-0.64
$\rho(q_h,Y)$	0.40	0.71	0.70	0.15	0.99
$\rho(q_h,YT)$	0.21	0.14	0.69	0.09	0.92
$\rho(q_h,YN)$	0.64	0.67	0.15	0.13	0.40
$\rho(RER,YT)$	0.28	0.44	0.88	0.70	0.90
$\rho(RER,YN)$	0.20	0.33	-0.39	-0.93	0.08
$\rho(RER,q_h)$	0.22	0.75	0.59	0.14	0.95

Notes: Output (Y), tradable output (YT), nontradable output (YN), consumption (C), investment (I), house price (q_h) and real exchange rate (RER) are in logs. Net exports (NX) are exports minus imports. Data series are seasonally adjusted and all series have been HP filtered. Standard deviations are reported as percentages. See the appendix for data sources.

The model matches the sectoral output volatilities closely, especially the volatility of the nontradable sector output. The correlations of sectoral output with the real exchange rate are also close to the data but the house price-real exchange rate correlation is higher and the volatility of the real exchange rate is lower compared to the data. The model generates a strongly countercyclical net exports-to-output ratio, which is an important feature of emerging market economies, but the volatility of net exports is higher than the data. The relative volatility of consumption in tradable units generated by the model is also higher than the data. The volatility of consumption is slightly less than output in Brazil when both are measured in tradable units, while the model produces a higher volatility. It is worth mentioning here that the empirical regularity of consumption being more volatile than output in emerging markets also holds in Brazil with a relative consumption volatility of 1.11 when real consumption and output are obtained in the standard way by measuring at constant prices. Since all of the variables reported in the table are in units of the tradable good, the relative volatility measure is different from the standard values reported in the literature.

To better understand the effect of collateral on business cycle regularities, we also report the moments for the case where the agents are still constrained in their borrowing but do not use any collateral. As in the impulse response analysis, the credit-to-output ratios are kept the same as in the benchmark model for all agents. The standard deviations obtained from the model in the no-collateral case show that the volatilities of all variables, except tradable output, decline when the collateral effect is shut down. This is consistent with the smaller responses obtained in the impulse response analysis in the case without collateral. Changes in collateral values generated by house price fluctuations amplify the effects of the shocks and lead to a higher volatility in the economy.

When the collateral effects are shut down, the model cannot match the pattern observed in the data in terms of the house price-sectoral output correlations. The correlation of house price and nontradable output decreases considerably, due to less strong demand for the nontradable good following a house price increase, and the correlation of house price and tradable output increases. Hence, the house price-sectoral output correlations are reversed, showing that the use of collateral in borrowing is key to generating the correlations observed in the data.

Even though the correlation of the house price with the real exchange rate gets slightly closer to the data in this case, the real exchange rate-sectoral output correlations worsen considerably. In particular, the correlation of the real exchange rate with nontradable output becomes negative and the correlation with tradable output increases significantly, showing that the real exchange rate dynamics generated by the model are also inconsistent with the data when the collateral effects are shut down.

We also study the role of borrowing constraints in generating the pattern with respect to the house price-sectoral output correlations. Since housing demand shocks affect directly the households and the main mechanism of the model mostly works through household demand, we study the implications of removing the borrowing constraint faced by the household.[9] In this set up, households are unconstrained in their borrowing and can borrow freely from international markets. To induce stationarity, we assume that households face convex bond holding costs of the form $\frac{\kappa}{2}(b_t^h - \bar{b}^h)^2$, where $\bar{b}^h$ is the steady-state debt level of the household (Schmitt-Grohe and Uribe, 2003). We set $\bar{b}^h$ such that the household debt-to-output ratio is the same as the baseline calibration and κ to a small value of 10^{-5} as in Neumeyer and Perri (2005) so that the bond holding costs do not affect the short-run dynamics of the model. We also adjust the housing preference parameter of the household, $\bar{\gamma}$, so that the residential housing-to-output ratio stays the same as in the benchmark model to provide a sensible comparison between models.

When households are unconstrained in their borrowing, the model predictions change considerably in several key dimensions. We observe a very high positive correlation between net exports and output, which is at odds with the well-documented empirical fact regarding the countercyclicality of net exports observed in emerging market economies. Since households can smooth consumption without any constraint, consumption volatility declines significantly, not matching the high consumption volatility observed in Brazil. The moments regarding house prices also worsen significantly when the credit constraint on households is removed. The model generates a weak positive correlation between house prices and nontradable output, as opposed to the strong comovement observed in the data. Tradable sector-house price correlation is also lower than the data. More importantly, in this case the house price correlations for two sectors are very close to each other and the model does not generate the key empirical pattern. Similar to the no-collateral case, not imposing credit constraints on households improves the correlation between house prices and

[9] We also study a case where all agents are unconstrained in their borrowing and the results are similar to the case where only households are unconstrained.

the real exchange rate but deteriorates the real exchange rate-sectoral output correlations considerably.

Finally, we analyze the ability of the model to match the data moments when only productivity shocks are used to understand the relative importance of the housing demand shock. Without a shock to housing demand, the volatilities of all of the variables decline. More importantly, the model cannot match the moments related to the house price. Specifically, the correlations of house price with sectoral output are inconsistent with the data. The model generates a very high correlation for house price and tradable output and a much lower correlation for nontradable output compared to the data, showing the importance of the mechanism generated by the housing demand shock in matching these correlations.

5.3 Housing Adjustment Costs

In this section, we analyze the effects of housing adjustment costs on the model dynamics by assuming that both households and firms face costs in adjusting the amount of real estate they own. In the benchmark model, agents can change their real estate holdings costlessly. In reality, for both residential and commercial real estate, selling and buying real estate entail substantial costs in terms of time and effort, as well as any direct costs like real estate commissions. In addition to this, there are costs associated with converting commercial real estate to residential housing and vice versa. In the benchmark model, we treat commercial and residential real estate as perfect substitutes and abstract from the costs of converting one type of real estate to the other. In this section, we proxy all of these costs by adjustment costs on the agents' stocks of real estate.

The functional form for the housing adjustment costs is $\frac{\varphi}{2}\left(h_t^s - h_{t-1}^s\right)^2$ for $s = h, eT, eN$. We analyze the implications of using adjustment costs by varying the parameter that determines the size of these costs, φ. Specifically, we set φ to two different values, 2.834 and 7.862, that respectively lead to 20% and 40% reduction in the response of residential housing to a housing demand shock in the first period. In other words, residential housing increases 20% and 40% less for a positive shock to housing demand compared to the benchmark. Figure 4 shows the impulse responses for these two cases together with the impulse responses for the benchmark model and Table 4 reports the moments.[10]

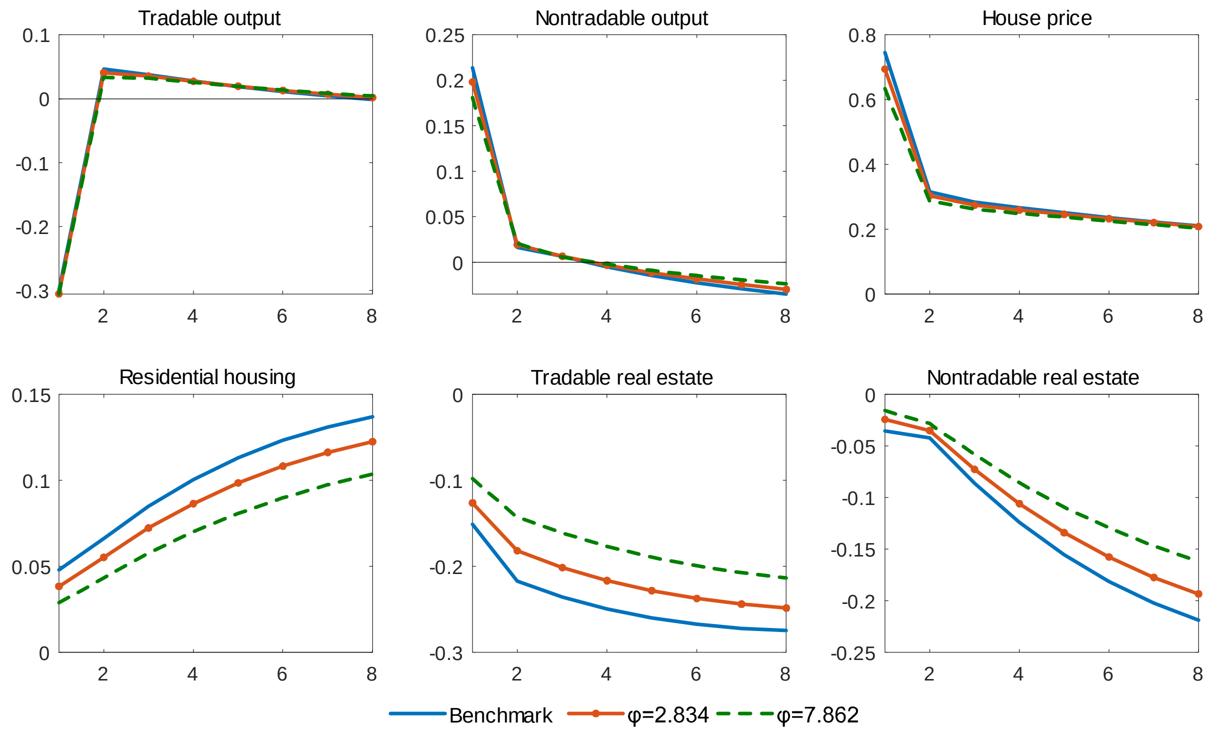

Figure 4. Positive shock to housing demand: Percent deviation of variables from their steady-state values for different values of φ

Both the impulse responses and the moment analysis show that housing adjustment costs have minor effects on the model dynamics and they do not change the main results of the model. Figure 4 shows that the changes in real estate following a housing demand shock decline for all agents as the size of the adjustment cost increases as expected. The responses of house price and nontradable output also decline as φ increases but this effect is quite small and it is even smaller for tradable output. The moments generated for different values of φ reported in Table 4 are also consistent with the small changes observed in the impulse reponses. Increasing adjustment costs reduces the volatilities of most of the variables and also leads to a slight decline in the house price-nontradable output correlation. However, the correlation of house price with nontradable output is still much higher than

[10] Since the effects of adjustment costs are quite small, we only show the impulse responses of a few main variables in Figure 4 in order to make the scale of the individual figures bigger.

its correlation with tradable output, showing that our main result holds in all cases. Even though the increase in the adjustment costs slows down the changes in the stocks of real estate, the house price increase is still sufficiently large to generate the effects observed in the benchmark model to a large extent.

Table 4. Housing adjustment costs

	Data	Benchmark model	$\varphi = 2.834$	$\varphi = 7.862$
$\sigma(Y)$	4.60	2.40	2.35	2.31
$\sigma(YT)$	3.04	2.39	2.36	2.31
$\sigma(YN)$	1.21	1.28	1.22	1.15
$\sigma(C)/\sigma(Y)$	0.98	1.45	1.45	1.44
$\sigma(I)/\sigma(YT)$	2.52	2.52	2.30	2.07
$\sigma\left(\frac{NX}{Y}\right)$	0.86	1.80	1.75	1.67
$\sigma\left(RER\right)$	8.95	1.56	1.57	1.56
$\sigma\left(q_h\right)$	3.74	3.74	3.54	3.31
$\rho(C, Y)$	0.96	0.89	0.89	0.89
$\rho(I, Y)$	0.90	0.81	0.82	0.84
$\rho\left(\frac{NX}{Y}, Y\right)$	-0.47	-0.41	-0.41	-0.40
$\rho\left(q_h, Y\right)$	0.40	0.71	0.70	0.70
$\rho\left(q_h, YT\right)$	0.21	0.14	0.13	0.14
$\rho\left(q_h, YN\right)$	0.64	0.67	0.64	0.61
$\rho\left(RER, YT\right)$	0.28	0.44	0.43	0.44
$\rho\left(RER, YN\right)$	0.20	0.33	0.29	0.25
$\rho\left(RER, q_h\right)$	0.22	0.75	0.75	0.75

Notes: Output (Y), tradable output (YT), nontradable output (YN), consumption (C), investment (I), house price (q_h) and real exchange rate (RER) are in logs. Net exports (NX) are exports minus imports. Data series are seasonally adjusted and all series have been HP filtered. Standard deviations are reported as percentages.

5.4 Robustness Analysis

In this section, we analyze the robustness of our results to changing the parameters of the model that we cannot calibrate to the Brazilian economy due to lack of data. Specifically, we change the parameters related to the factor shares in the production functions, the housing preference in the utility function and the working capital requirement. Table 5 shows the business cycle moments for different parameterizations of the model. In all cases, we keep the credit-to-GDP ratios the same as in the benchmark calibration by adjusting the values of the LTV ratios, m^h, m^{eN} and m^{eT}.

First, we change the shares of capital and real estate in the production functions for the tradable and nontradable sectors. In the benchmark calibration, we use the values calibrated from the US data, which are consistent with the conjecture that the tradable sector is more capital intensive whereas nontradable sector is more real estate intensive. In the robustness exercise, we change the input shares such that they are the same in both tradable and nontradable sectors. More specifically, we set the share of capital, α, and the share of real estate, μ, equal to 0.25 and 0.15, respectively. When we use these values in the production functions, we observe a slight increase in the correlation between house prices and tradable sector output and a slight decrease in the correlation between house prices and nontradable sector output. However, nontradable sector is still more strongly correlated with the house price and the key pattern with respect to house prices and sectoral output correlations still holds. The rest of the moments mostly stay the same.

Next, we increase the residential housing stock-to-GDP ratio to 150%, which is equal to 100% in the benchmark calibration, by changing the parameter that governs the households' preference for housing in the utility function, $\bar{\gamma}$. The increase in the stock of housing mainly affects the house price volatility, with very minor effects on the other moments. More importantly, our main result regarding the correlation between house prices and sectoral output holds when we increase the housing stock-to-GDP ratio.

Finally, we change the working capital parameter, θ, to analyze the importance of the working capital requirement for our results. In the baseline calibration, we set $\theta = 0.25$, a value that has been used in the literature for emerging market economies. We observe that, as the working capital parameter increases, the correlation between tradable output and house price strengthens. However, the house price-nontradable output correlation is not affected and nontradable output continues to be more strongly correlated with house prices compared to tradable output in all cases. Given these results, we conclude that, for reasonable levels of the working capital requirement, our model can match the key pattern we observe in the data for sectoral output and house prices.

Table 5. Robustness analysis

	Data	Benchmark model	Equal factor shares	Higher residential housing-to-output ratio	Changes in the working capital parameter	
					$\theta = 0$	$\theta = 0.5$
$\sigma(Y)$	4.60	2.40	2.40	2.43	2.29	2.46
$\sigma(YT)$	3.04	2.39	2.28	2.44	2.43	2.44
$\sigma(YN)$	1.21	1.28	1.16	1.33	1.19	1.30
$\sigma(C)/\sigma(Y)$	0.98	1.45	1.43	1.47	1.59	1.31
$\sigma(I)/\sigma(YT)$	2.52	2.52	2.34	2.65	2.68	2.24
$\sigma\left(\frac{NX}{Y}\right)$	0.86	1.80	1.72	1.87	2.10	1.49
$\sigma(RER)$	8.95	1.56	1.61	1.57	1.71	1.44
$\sigma(q_h)$	3.74	3.74	3.67	4.04	3.87	3.57
$\rho(C,Y)$	0.96	0.89	0.90	0.88	0.86	0.91
$\rho(I,Y)$	0.90	0.81	0.83	0.81	0.79	0.83
$\rho\left(\frac{NX}{Y},Y\right)$	-0.47	-0.41	-0.45	-0.42	-0.43	-0.35
$\rho(q_h,Y)$	0.40	0.71	0.73	0.71	0.70	0.71
$\rho(q_h,YT)$	0.21	0.14	0.23	0.13	-0.03	0.28
$\rho(q_h,YN)$	0.64	0.67	0.62	0.68	0.65	0.66
$\rho(RER,YT)$	0.28	0.44	0.50	0.42	0.21	0.63
$\rho(RER,YN)$	0.20	0.33	0.29	0.36	0.31	0.28
$\rho(RER,q_h)$	0.22	0.75	0.76	0.74	0.77	0.72

Notes: Output (Y), tradable output (YT), nontradable output (YN), consumption (C), investment (I), house price (q_h) and real exchange rate (RER) are in logs. Net exports (NX) are exports minus imports. Data series are seasonally adjusted and all series have been HP filtered. Standard deviations are reported as percentages. Column 3 shows the results when the factor shares are set to be the same across sectors. In Column 4, we increase the residential housing-to-output ratio to 150%. In the last two columns, we change the working capital parameter.

6 Conclusions

Housing market fluctuations received significant attention in the literature since the Global Financial Crisis of 2007-08. We contribute to this literature by studying the effect of house price changes on sectoral reallocation and output dynamics in emerging market economies, emphasizing the role played by collateral values and borrowing.

We first examine the empirical relationship between house prices and sectoral output. The correlations for a sample of emerging market and advanced economies show that house prices are more strongly correlated with the nontradable sector compared to the tradable sector and the differences between the two sectors are larger in emerging market economies. We then analyze this relationship using a PVAR for emerging market economies, and find that a house price shock generates a larger response in the nontradable sector, consistent with the pattern observed in the correlations. To explain these empirical facts, we develop a two-sector small open economy real business cycle model with collateral constraints and study the model dynamics generated by shocks to housing demand.

We show that an increase in house prices leads to an increase in aggregate demand and a real exchange rate appreciation, which results in an expansion in the nontradable sector and a contraction in the tradable sector. Without collateral in the borrowing constraints, an increase in the house price does not lead to an increase in borrowing. This changes the responses in the real exchange rate and sectoral output, generating an expansion in tradable output. As a result, the model cannot match the pattern observed in the data in terms of the house price-sectoral output correlations. Additionally, the general equilibrium effects of the housing demand shock are muted in the absence of collateral, showing that collateral effects can generate sizeable amplification in the economy. We also remove the borrowing constraint on households to evaluate how the model responds to house price changes when households are unconstrained in their borrowing. Similar to the no collateral case, this set up cannot generate the comovement pattern we observe in the data with respect to house prices and sectoral output.

Our results underline the importance of collateral constraints in understanding the linkages between house prices, real exchange rate and sectoral dynamics. A key policy implication of our analysis is that an increase in house prices may hurt the tradable sector by shifting resources towards the nontradable sector through an increase in borrowing and aggregate demand. We believe that understanding the mechanisms that link house prices, borrowing dynamics and sectoral output is necessary to fully evaluate the effects of housing market fluctuations on the economy.

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Appendix

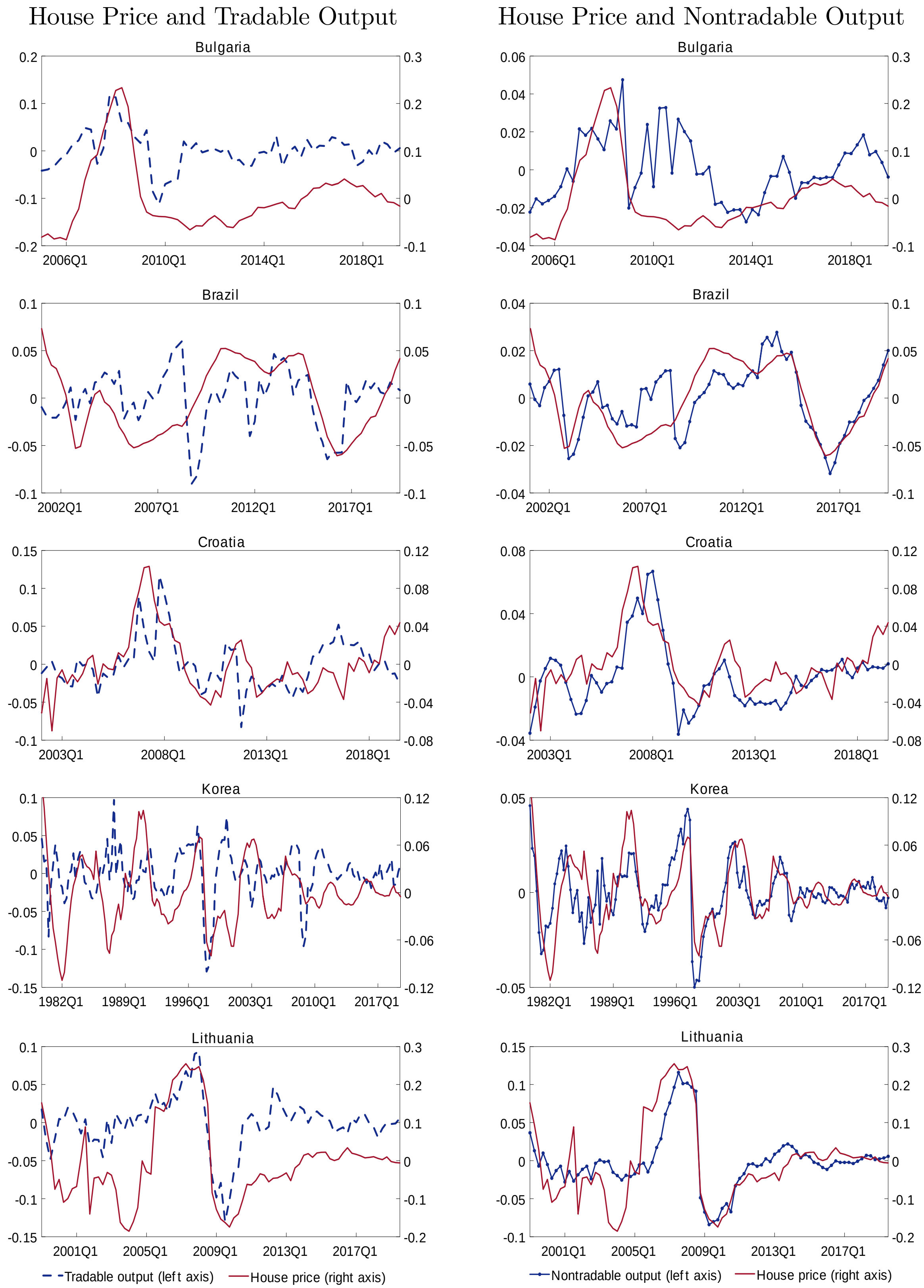

Figure 5. House price and sectoral output in emerging markets

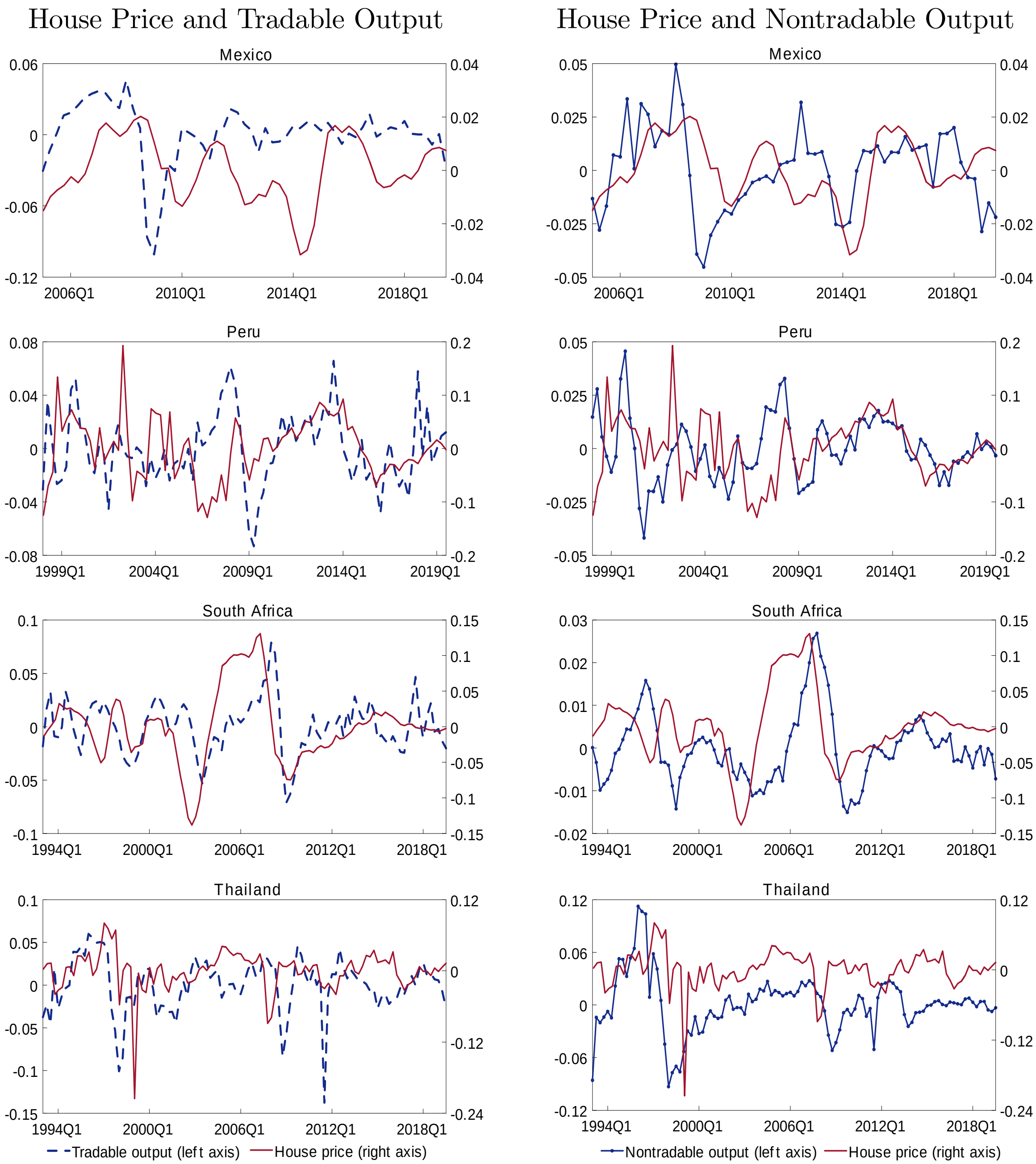

Figure 5 (continued). House price and sectoral output in emerging markets

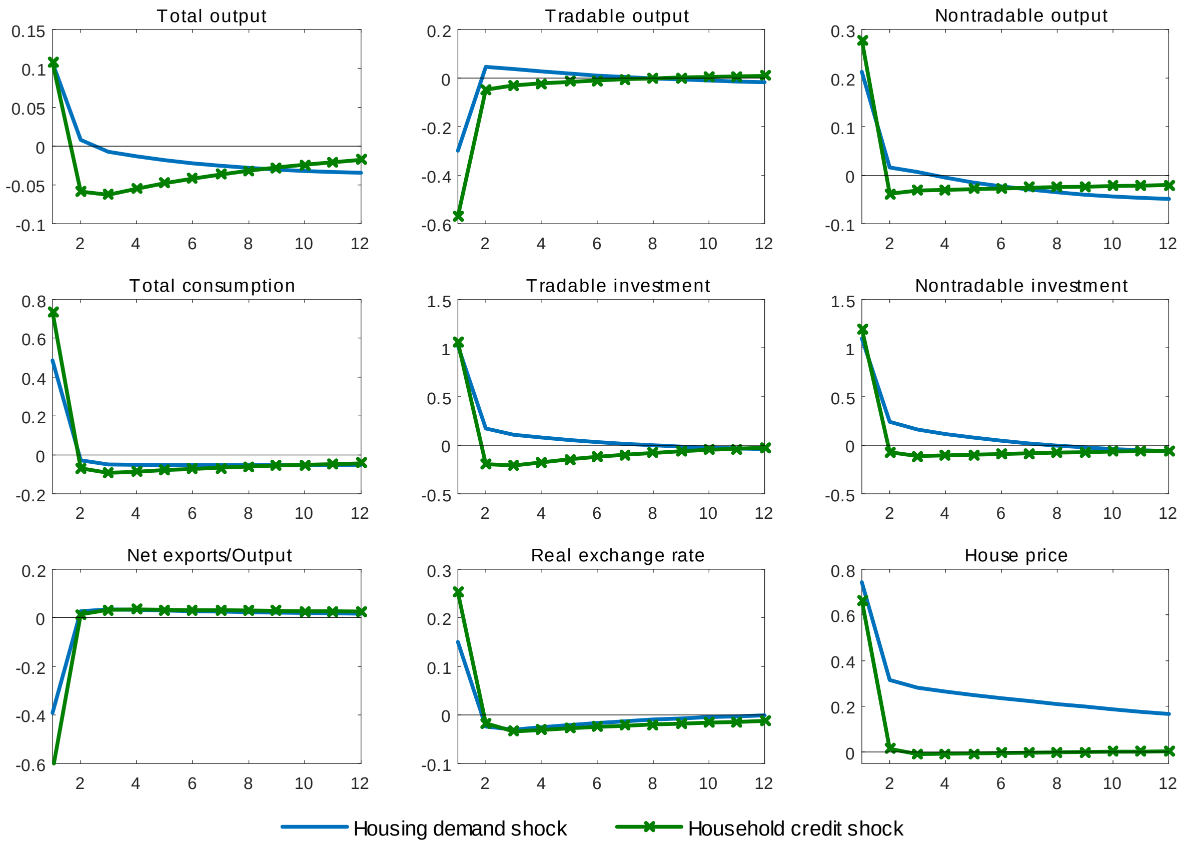

Figure 6. Positive shocks to housing demand and household credit: Percent deviation of variables from their steady-state values in the benchmark model

Data Appendix

Cross-sectional Data

The data on sectoral output used in Table 1 come from OECD Quarterly National Accounts Database except for Croatia, Peru and Thailand, which are obtained from their respective central banks. For each country, to construct tradable sector output, we use the sum of manufacturing and agriculture, forestry and fishing, whereas nontradable sector output is the sum of construction and services. The house price data are real residential property prices index (2000=100) and come from the BIS property price statistics. All series are seasonally adjusted, logged and HP-filtered.

Table A1. Data sources for the sectoral output and house price series

Countries	Time period	Source
Brazil	1996Q1-2019Q4	OECD, BIS
Bulgaria	2005Q1-2019Q4	OECD, BIS
Croatia	2002Q1-2019Q4	Croatian National Bank, BIS
Korea	1980Q1-2019Q4	OECD, BIS
Lithuania	1999Q1-2019Q4	OECD, BIS
Mexico	2005Q1-2019Q4	OECD, BIS
Peru	1998Q1-2019Q4	Central Reserve Bank of Peru, BIS
South Africa	1993Q1-2019Q4	OECD, BIS
Thailand	1993Q1-2019Q4	Bank of Thailand, BIS
Canada	2007Q1-2019Q4	OECD, BIS
France	1994Q1-2019Q4	OECD, BIS
Germany	1992Q1-2019Q4	OECD, BIS
Italy	1980Q1-2019Q4	OECD, BIS
Japan	2008Q1-2019Q4	Ministry of Economy, Trade and Industry, BIS
UK	1996Q1-2019Q4	OECD, BIS
USA	2005Q1-2019Q4	OECD, BIS

Data for Brazil

The construction of the series used in the model solution is explained below.

Sectoral output: Tradable sector output is the sum of manufacturing and agriculture, forestry and fishing. Nontradable sector output is the sum of construction and service sector output.

Labor Input: Given the lack of data on average hours worked, we measure sectoral labor input by sectoral employment. Since sectoral employment data are given as an index for each sector, we cannot add up the series for different sectors to reach total employment figures for tradable and nontradable sectors. Therefore, we use the employment indices for manufacturing and services as the employment series for tradable and nontradable sectors, respectively.

Capital Stock: The capital stock data are generated using a perpetual inventory method. Since sectoral investment data are not available, we use total gross fixed capital formation to compute an aggregate capital stock series and use this series for both sectors. For the perpetual inventory method, we use a yearly depreciation rate of 0.08 as Meza and Quintin (2007). To set the initial capital stock, we follow Young (1995) and Meza and Quintin (2007) and assume that the growth rates of investment in the first five years of the series are representative of the growth rates of investment in previous years.

Total Factor Productivity: To construct the total factor productivity for each sector, we use sectoral GDP and employment indices described above. The same capital stock series is used for both sectors. Since the gross fixed capital formation series includes equipment, machinery and structures, the generated capital stock series corresponds to the sum of capital stock and real estate. Therefore, in the calibration of the TFP shocks, we set the share of capital stock such that it is equal to the sum of the shares of real estate and capital used in the model. The computed TFP series are seasonally adjusted and HP filtered, which are then used to estimate the AR(1) processes for the productivity shocks.

Real interest rate: The series for the real interest rate is computed using the procedure followed by Neumeyer and Perri (2005). The real interest rate for Brazil is computed as the

US real interest rate plus the sovereign spread for Brazil. The sovereign spread is measured by J.P. Morgan's Emerging Markets Bond Index Global (EMBIG). The US real interest rate is computed by subtracting expected inflation rate from the interest rate on 90-day US Treasury bills. Expected inflation in period t is computed as the average of US GDP deflator inflation in the current period and in the three preceding periods.

Business Credit: For sectoral business credit, we use the "Credit operations outstanding by economic activity" data from the Central Bank of Brazil. Tradable sector credit is the sum of the series for agriculture and industry, nontradable sector credit is measured by the series for the service sector. The GDP data we use for computing the credit-to-GDP ratios are annual level series in national currency and current prices.

Household Credit: Household credit data is the "Total credit to households" series, which is obtained from the Bank for International Settlements (BIS) "Long series on credit to the private non-financial sector" dataset. We use the same GDP series we use for business credit to compute the household credit-to-GDP ratio.

Sources and definitions of the data used in calibration:

- Nominal GDP: GDP at current prices, OECD.
- Real GDP: GDP at 1995 prices, OECD.
- Investment: Gross fixed capital formation at 1995 prices, OECD.
- Consumption: Final consumption expenditure of resident households at 1995 prices, OECD.
- Net exports: Exports minus imports of goods and services, OECD.
- Indexes of total employment in manufacturing and services: Registered Employees Index - Manufacturing; Formal Employees Index - Services, Central Bank of Brazil
- Real house prices: Real residential property prices, BIS.
- Household credit: Total credit to households, BIS.
- Sectoral business credit: Credit operations outstanding by economic activity, Central Bank of Brazil.
- US Treasury bill rate: Federal Reserve Economic Data (FRED)

- US GDP deflator inflation: International Financial Statistics, IMF.

- Sovereign spread: Emerging Markets Bond Index Global (EMBIG), J.P. Morgan.