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Zhen Huo
New York University

José-Víctor Ríos-Rull
University of Pennsylvania,
Federal Reserve Bank of Minneapolis,
UCL, CAERP, CEPR, and NBER

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# Financial Frictions, Asset Prices, and the Great Recession*

Zhen Huo
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**Abstract**

We study financial shocks to households' ability to borrow in an economy that quantitatively replicates U.S. earnings, financial, and housing wealth distributions and the main macro aggregates. Such shocks generate large recessions via the negative wealth effect associated with the large drop in house prices triggered by the reduced access to credit of a large number of households. The model incorporates additional margins that are crucial for a large recession to occur: that it is difficult to reallocate production from consumption to investment or net exports, and that the reductions in consumption contribute to reductions in measured TFP.

Keywords: Balance Sheet Recession, Asset price, Goods market frictions, Labor market frictions
JEL classifications: E20, E32, E44

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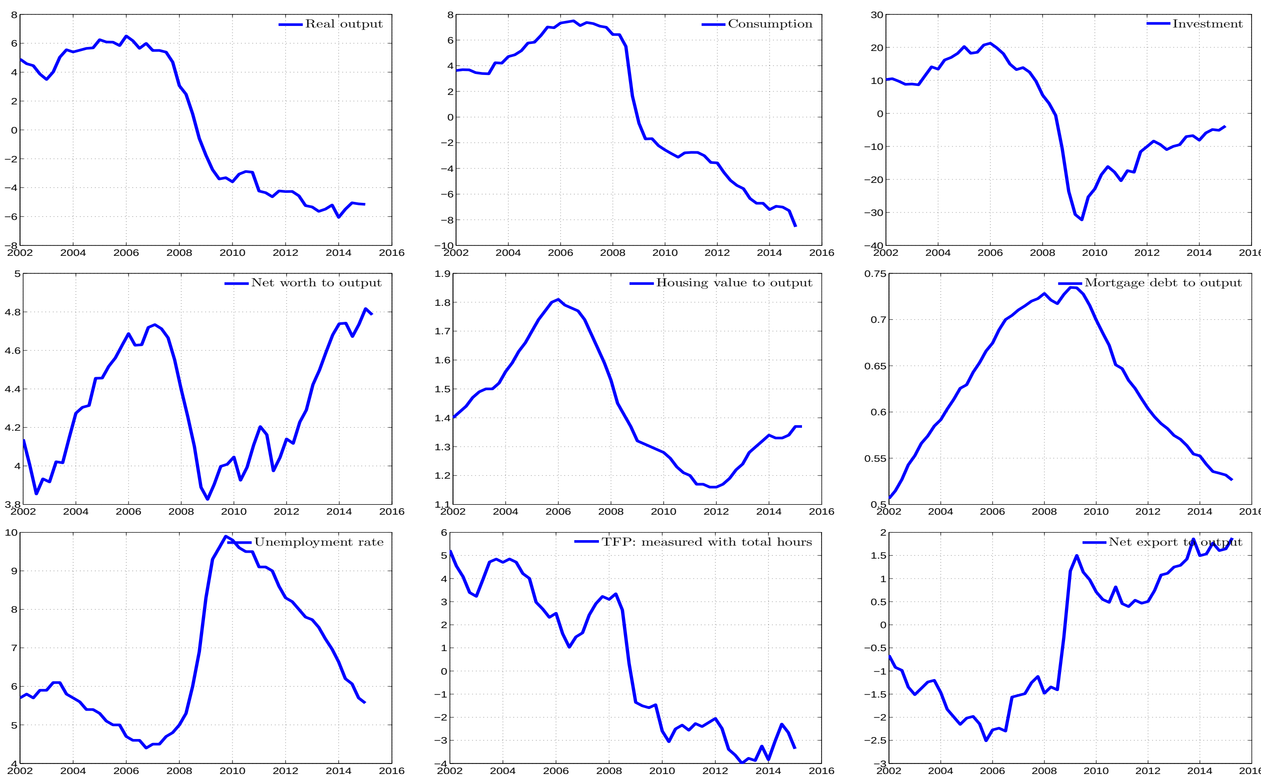
# 1 Introduction

The Great Recession in the United States has several notable features (see Figure 1): (1) (Detrended) output dropped dramatically, about 9 percentage points. (2) Private consumption and investment both dropped even more, about 10% and 30%, respectively, below trend. (3) Similarly, the value of house prices suffered a huge loss after some large gains before the Great Recession started. (4) An unprecedented credit cycle began on the household side. The debt-to-income ratio quickly increased to its historically highest level (about 2.3) until 2008 and has declined sharply since the crisis began. (5) The unemployment rate climbed to 10% in 2009 and remained at a high level for a fairly long period. (6) Measured total factor productivity (TFP) declined. (7) Net exports increased by about 3% of GDP from 2008 to 2010.

Figure 1: Aggregate Performance of the U.S. Economy




Note: Real Output, Consumption, Investment and TFP are linearly detrended logs.

Motivated by these facts, we build a model economy to explore the extent to which a recession can be triggered by a shock to households' access to house financing. Borrowing difficulties reduce house prices, which in turn reduces wealth, especially for a large number of highly leveraged households. The response is to cut consumption directly (and investment indirectly), prompting a recession. In an economy with high wealth inequality, like that of the United States, this mechanism triggers a large recession.

Our model economy includes two crucial features of the U.S. economy that make it nontrivial for financial shocks to households' ability to borrow to generate a large recession: that total wealth is plentiful and that investment and net exports are mechanisms for society to save into the future. Consequently, our model economy requires the explicit inclusion of certain ingredients to generate a large recession as a result of a financial shock. The first ingredient is that wealth must be very unequally distributed, and a large number of households must use the financial system to purchase houses. The second ingredient, as in Huo and Ríos-Rull (2013) and Midrigan and Philippon (2011), is real rigidities that make it quite costly to have a fast expansion of the tradable sector and a rapid increase of exports when consumption falls. The third ingredient is a housing sector with prices that respond to households' willingness to buy and that can dramatically amplify the recession in a fashion similar to that posed by Kiyotaki and Moore (1997). The fourth ingredient is goods market frictions that move total factor productivity endogenously and that exacerbate the recession by reducing profits.[1,2] The finally ingredient is some labor market frictions that make hiring costly and that prevent a dramatic fall in wages.

The model economy that we pose is of the Bewley-Imrohoroglu-Huggett-Aiyagari variety, extended to include multiple sectors of production (tradables and nontradables), both capital and houses (which we model as being in fixed supply, such as land, and that need to be purchased in order to be enjoyed), endogenous productivity movements arising from frictions in the goods markets, and various job market frictions. A crucial feature in our economy is that households' borrowing has to be collateralized with housing. As in all market incomplete economies, more adverse trading possibilities for households result in higher long-run output and wealth. However, the transition involves a recession. The keys to the recession are the inability of the economy to turn on a dime from an economy geared to consumption to a savings-oriented economy that produces investment and exports goods, the amplification effects of the housing prices, and the endogeneity of production.

The main financial shock that we consider is a shock to the loan-to-value ratio and to the interest rate markup on mortgages. The former moves unexpectedly from 20% to 40%,[3] and the latter goes up from zero to 50 basis points. Such a shock generates a drop of 3.5% in output, 6.4% in consumption and 29.0% in investment (the increase in net exports accounts for the difference). Unemployment jumps from 6 to 8.8%, house prices fall by 18%, household debt falls by 33%, and total wealth falls by 7.7%. There is also an endogenous fall in TFP of 1.5%.

The financial shock generates a recession because the difficulty in accessing credit dramatically reduces housing demand and, with it, housing prices. Households want to increase their wealth both to recover the level of lost housing (for those who had a binding collateral constraint) and to bear the higher unemployment risk and lower borrowing capacity (for those who did not have a binding collateral constraint). The new financial terms

[1]Frictions in goods markets have been posed in Bai, Ríos-Rull, and Storesletten (2011), Bai and Ríos-Rull (2015), and Huo and Ríos-Rull (2013), where they are directly responsible for total factor productivity changes, and in Petrosky-Nadeau and Wasmer (2015), where they drastically amplify and change the properties of productivity shocks. The mechanism involves households bearing some of the efforts to extract the output of the economy in an environment with search frictions. Our environment has the novel implication that search effort increases in the face of a negative wealth effect.

[2]Fernald (2012) shows that total factor productivity has dropped since 2008 and started to recover after 2010.

[3]This shock is usually referred to as an MIT shock.

imply that all households see an increase in their optimal saving-to-income ratio. As a result, households cut their consumption, which results in lower prices, a lower occupation rate, and lower profits in the nontradable goods sector and therefore lower employment and investment. The reduced hiring further increases households' unemployment risk and precautionary saving motive. The drop in house prices has two separate but related effects on households: first, it further tightens the collateral constraint and forces more households to reduce their debt involuntarily; second, it weakens the balance sheets all homeowners, which is followed by a reduction of consumption through wealth effects. These forces reinforce each other and form a vicious cycle. For the recession to occur, the tradable sector cannot expand too fast.

We explore many versions of our economy to see how various margins affect our findings. It turns out that the change in the loan-to-value ratio accounts for about 60% of the fall in output, but the increased markup in mortgages has more long run permanent effects via its increase on the user cost of ownership of housing for the poorest households. The role of falling house prices is absolutely central. In its absence, the fall in output would be less than one-third of a percentage point. We pose two frictions to impede a fast growth of net exports, adjustment costs and decreasing returns to scale, and each one of them reduces output by about 0.60%. The endogenous fall in TFP is quite an important contributing mechanism: in its absence, the fall in output would be less than one-half.

We extend our model economy in two ways. First, we allow for (unexpected) household default when we pose a slightly larger shock that results in a fall in house prices of 22% rather than 18% (enough to generate an empty budget set in some households despite the large loan-to-value ratio of the baseline economy). The losses are absorbed by the mutual funds that issued the mortgages. Under these circumstances, the fall in output is 4.4% rather than 3.5%. We do not pose this economy as the baseline on the grounds of having lenders lose money unexpectedly. Second, we change preferences over housing to reduce the number of homeowners that match the U.S. homeownership ratio. When adjusting the shock to match the same fall in house prices, we obtain a similar sized recession.[4]

Our model has rich cross-sectional implications that can readily be compared with those in the data. First, in term of the heterogeneous response of consumption, Mian, Rao, and Sufi (2013), Mian and Sufi (2014), Petev, Pistaferri, and Eksten (2011), and Parker and Vissing-Jorgensen (2009) document that the households that lose the most are the ones that cut their consumption the most. Mian, Rao, and Sufi (2013) and Mian and Sufi (2014) show, using spatial data, that it is in regions that experienced a larger house price drop where consumption fell the most and that leveraged and underwater households cut their consumption more aggressively. Parker and Vissing-Jorgensen (2009) and Petev, Pistaferri, and Eksten (2011), using Consumer Expenditure Survey (CEX) data, show that it is the medium to rich households ( in terms of both income and wealth) who reduce consumption the most.[5] In

[4]This economy is much more complicated than the baseline, and we thus leave it as an extension.

[5]The CEX data are likely to miss the very high income households. See Bricker, Henriques, Krimmel, and Sabelhaus (2015) and Sabelhaus, Johnson, Ash, Swanson, Garner, Greenlees, and Henderson (2013).

our extended model, where we match the U.S. home-ownership rate, the households who drop consumption the most are those whose wealth drops the most. These households are highly leveraged or have a large share of housing in their total net worth, and they are concentrated in the middle of the wealth distribution (30%-80%).[6] The poorest households do not own houses, and their consumption actually increases slightly because of lower nontradable prices. The majority of households own some housing and suffer from a weakened balance sheet. Thus, in our (extended) model economy, consumption inequality falls during the recession, which is the Parker and Vissing-Jorgensen (2009) way of summarizing the outcome. Second, in terms of the heterogeneity of unemployment risk, Fang and Nie (2013) and Lifschitz, Setty, and Yedid-Levi (2015) document that during the Great Recession, workers with the lowest educational attainment bore the greatest unemployment risk because of a much higher job separation probability. In our model, the peaks of the unemployment rate among different groups of workers range from 5% to 14%, which replicates the key feature of the data.

We also use our model to explore the implications of an expansion of credit followed by a posterior contraction, both caused by financial shocks to households' ability to borrow. Predictably, the economy experiences an expansion followed by a recession. The latter is much more severe than the former. Both changes of conditions generate immediate price changes, but the effects on expenditures have different temporal dimensions. The household response to the increase in riches coming from higher house prices is to slowly increase consumption. The response to the opposite shock is, however, much faster. Households do not like to be too close to their constraints and will try hard to accumulate assets.

Although we pose a fairly complicated model economy, our formulation has some shortcomings that future work should address. First, we model the housing market as frictionless. Both house size and the size of its financing can be costlessly resized. A growing amount of evidence that these assumptions are inappropriate (see, for instance, Kaplan and L. Violante (2014)). Because of this, the financial shock that we pose is to the loan-to-value ratio, which may not be the relevant margin where the financial shock affected households (see Cloyne, Ferreira, and Surico (2015)). All this suggests that a richer model of housing and mortgaging decisions may be important. Second, in our economy, firms that produce investment goods can redirect their output to exports costlessly when investment falls. Yet, exports always take time to expand (see Alessandria, Pratap, and Yue (2013)), and the investment-producing sectors also suffered during the Great Recession. A richer model should have more sectors and a mechanism for investment-producing firms to suffer during the recession. This is particularly the case if we think of construction of both business structures and houses, which are sectors that have the features of nontradables rather than tradables. That the recession occurred in all developed economies, making exports more difficult, makes this shortcoming more relevant. Third, our model has a constant real interest rate. This is partly to relate it to the zero bound literature

[6] In our model, the loss of net worth mainly comes from the decline in housing prices and housing wealth accounts for a relatively small fraction of the total wealth of the richest households. Our model misses the large drop in the prices of financial assets, which is what may account for the large drop in consumption of the richest households in the sample used by Parker and Vissing-Jorgensen (2009).

and partly as a humility cure for our lack of understanding of what internal mechanisms, if any, are responsible for the fall in real interest rates of the last few years. Fourth, and perhaps most important, a financial shock should not be a primitive, as it is in our model, but rather an outcome of deeper mechanisms.

This paper is related to several strands of the literature. First, it is part of the literature that attributes the recession to household financial distress, which is partly inspired by the empirical work of Mian and Sufi (2011, 2014) and Mian, Rao, and Sufi (2013). Most of these papers assume that there are two types of agents, borrowers and savers. For example, Eggertsson and Krugman (2012), Guerrieri and Iacoviello (2013), and Justiniano, Primiceri, and Tambalotti (2015) explore the interaction between the tightening of financial constraints and the zero-bound of nominal interest rates. When borrowers are forced to reduce their debt, the depressed demand puts downward pressure on the interest rate. To make a recession happen, nominal rigidities have to be present and the zero bound has to be binding. The problem, according to these papers, is that nominal prices cannot adjust to equate supply and demand. This is not the mechanism that we work out in our paper. Quantitatively, the recessions generated in the saver-borrower type of model are typically small, because the savers and borrowers often move in the opposite direction and wash out in the aggregate.

Midrigan and Philippon (2011) consider a richer environment in which different regions are distinguished by their initial debt-to-income ratio, but share the same interest rate. Both the rich and the poor are liquidity constrained, but only the poor are credit constrained. A shock to the collateral constraint for liquidity significantly reduces aggregate demand if the rich cannot quickly convert credit into liquidity. As in our paper, Midrigan and Philippon (2011) assume labor reallocation costs and wage rigidity to prevent households from working harder or moving to a tradable sector capable of accommodating the lack of demand. Unlike in our paper, where the change of house prices is driven by the financial shocks, the movement of housing price in Midrigan and Philippon (2011) is mainly triggered by a wedge in the Euler equation, which can be interpreted as preference shocks or news shocks. In their model with savers and borrowers, it is difficult for liquidity shocks or credit shocks to generate large recessions. The reason for this, we think, is that savers can easily transform their savings into consumption unless assuming a large adjustment cost. The savers will pick up the slack and leave total spending only slightly affected. Because their economy has no increased unemployment risk, households do not reduce their consumption due to a precautionary motive. All the papers discussed so far have only two types of agents that differ in patience so one group is borrowing subject to some constraint and the other is saving. Consequently, the response of the economy to the credit crunch is built in the assumptions that govern the size of the borrowing group and the magnitude of their constraints. We think that any attempt to measure the effects of a credit crunch has to be made in a model with a wealth and income distribution that is consistent with that in the U.S. Only in this manner the model could capture the heterogeneous response of the different households to the financial shock and its aggregate implications.

A paper that partially partially closes this gap is Guerrieri and Lorenzoni (2011), who study the effects of a reduction in the borrowing limit in a Huggett (1993) type economy where households borrow from each other and aggregate wealth is zero (except in an extension with consumer durables). A tightening of the borrowing constraint induces the poorest households to increase their work effort and their savings, and the rich end up consuming more and working less. Although the poor consume less and work more, the overall effect in the economy is that output declines because of the reduction in labor of the very high skilled workers. Total working hours, however, increase because most households work more. Guerrieri and Lorenzoni (2011) pose the same trigger as our paper, yet the consequences are very different, even though theirs is a world in which the lack of aggregate wealth makes the increased difficulty in borrowing potentially more painful. Crucially, the environment in Guerrieri and Lorenzoni (2011) misses the amplification effects of house price drops on household wealth, the contribution of endogenous productivity, and the existence of real frictions that make it difficult to switch from producing for consumption to producing for wealth accumulation (investment and net exports). In Huo and Rios-Rull (2015) we explored the effects of a credit tightening in a heterogeneous market economy with endogenous productivity. Here, households consume two goods, one of which has to be produced by others and is subject to a search friction. Increased difficulty in accessing credit translates into a lower ability to obtain consumption by poor people. As in Guerrieri and Lorenzoni (2011), the absence of housing implies that the redistributive impact of the shock in favor of the rich makes the aggregate impact small.

A second strand of the literature related to this paper is the exploration of the boom and bust in the housing market arising from changes in borrowing requirements. Kiyotaki, Michaelides, and Nikolov (2011) explore the causes of the housing market boom in the 2000s and its redistributive effects. Favilukis, Ludvigson, and Van Nieuwerburgh (2012) focus on the effects of exogenous changes in financial conditions on house prices that operate via endogenous changes in the risk premium in economies with high risk aversion. Garriga, Manuelli, and Peralta-Alva (2012) explain the boom and bust in the housing market in a small open economy. Ríos-Rull and Sánchez-Marcos (2008b) explore the implications for housing prices and transactions of business cycles. Greenwald (2015) considers both the loan-to-value ratio constraint and the debt-to-income ratio constraint and shows that the constraint that is more relevant in shaping housing prices depends on the state of the aggregate economy. Chen, Michaux, and Roussanov (2013), Kaplan, Mitman, and Violante (2015), and Gorea and Midrigan (2015) include long-term mortgage debt and explore the effects of changes in housing prices on aggregate consumption. Most of the papers discussed here assume a fixed labor supply, which prevents them from linking the change in housing market conditions to the business cycle. Our paper shares with these papers the view that the change in the borrowing limit has important implications for housing price dynamics, and we further explore the two-way feedback between housing prices and aggregate fluctuations.

A third strand of the literature deals with goods market frictions. Our approach to modeling goods market frictions builds on Bai, Ríos-Rull, and Storesletten (2011), Bai and Ríos-Rull (2015), and Huo and Rios-Rull (2015), and we extend it to accommodate multiple varieties of goods. Alessandria (2009) and Kaplan and Menzio (2013) also study the role of goods market frictions in business cycle analysis. Our model differs from theirs in that in these two papers, the occupancy rate of sellers is independent of households' search effort, which is what makes measured TFP positively correlated with aggregate demand in our model. Petrosky-Nadeau and Wasmer (2015) show that the search in the goods market can greatly amplify and propagate the effects of technology shocks on labor markets. Michaillat and Saez (2013) also consider an environment with a variable occupation rate. Unlike the rest of the literature that poses two equilibrium conditions to determine both the price and market tightness, this paper ignores one of those conditions, leaving only market clearing and resulting in multiple equilibria, which they deal with by setting an exogenous price level.

Section 2 poses the model economy and describes our modelization of the financial shocks. Section 3 discusses how we map the model economy to the data so that it looks like the U.S. economy. Section 4 does a steady-state analysis that describes the long-run implications of the financial shocks. Section 5 explores the effects of the financial shocks and analyzes the margins that matter. Section 6 discusses the extensions of the model economy that we study (default and preferences with zero housing) and shows how our findings remain robust. Section 7 explores the cross-sectional implications of our model for the recession and compares them with those in the data. Section 8 studies the effects of a credit expansion followed by a contraction—a boom and bust cycle that arises from exogenous changes in the accessibility of household secure credit— and discusses how to interpret the last 15 years under that light. A brief conclusion follows. An appendix includes details on the construction of data, discusses shopping effort and shopping time, and provides additional tables and graphs of interest.

## 2 The Model Economy

We consider a Bewley-Imrohoroglu-Huggett-Aiyagari type model in a small open economy (i.e., the interest rate is set by the rest of the world). There are two produced goods, tradables and nontradables, subject to adjustment costs to capital and labor that make it hard to quickly reallocate resources across sectors. Nontradable goods are subject to search frictions, as in Bai, Ríos-Rull, and Storesletten (2011) and Huo and Ríos-Rull (2013): firms and consumers have to search for each other before transactions can take place. Consumers exert costly effort to get around a standard search friction. The labor market is also subject to frictions: firms face hiring costs and workers have to search for a job. Households own financial assets and housing. Financial assets are held in mutual funds that in turn own all the assets other than privately owned housing, which are shares of tradable and nontradable producing firms, mortgages, and loans to and from the rest of the world. Crucially, borrowing has to be collateralized by housing.

## 2.1 Steady States

We start by posing the model economy in steady state. Later we discuss the financial shocks. Search frictions in the goods and labor markets crucially shape the problem of households and firms, so we start by describing them.

**Goods Markets** The tradable good, which is denoted by $T$ and is the numeraire, can be used for consumption, investment, and exporting. The tradable sector is competitive. Nontradables, denoted by $N$, can be used only for local consumption and are subject to additional frictions.

There is a measure 1 of varieties of nontradables $i \in [0, 1]$, and each variety is produced by a firm. Each firm owns a measure 1 of locations, some of which will be matched with households and some that will not. Consumers have to exert search effort to find varieties. Firms, on the other hand, search costlessly.

Matches of varieties (firms) and households are formed by combining the total measure of varieties, 1, and the aggregate measure of searching effort by households, denoted $D$, via a constant returns to scale matching function. When a household matches a variety, it is randomly allocated to one of its locations. Firms do not know in advance which locations will be the ones matched with a household. This matching process ensures that all firms-varieties get the same number of customers or the same occupancy rate.

We write the number of matches by $M^g(D, 1)$ and market tightness by $Q_g = \frac{1}{D}$. The probability that a shopper (a unit of shopping effort and not an agent) finds a variety is

$$\Psi^d(Q_g) = \frac{M^g(D, 1)}{D}, \tag{1}$$

while the measure of shoppers that firms have access to is

$$\Psi^f(Q_g) = M^g(D, 1). \tag{2}$$

Note that $\Psi^f(Q_g)$ is also the fraction of shops or locations of each variety that are filled by a consumer.[7]

Recall that firms do not know in advance which of its locations will be matched with a household, nor do they know which type of household (with which willingness to spend) it will be matched with. They do, however, know the probability that each location will be matched and the probability distribution of household types it will be matched with. We assume that firms post a price in all their locations and commit to it regardless of the household type that shows up. Firms honor all orders.[8]

[7] Given the passive nature of the locations side, to find households we could have directly written functions $\Psi^d(D)$ and $\Psi^f(D)$.

[8] These assumptions amount to random search with price posting. This is an arbitrary but simplifying choice. An obvious alternative is competitive search where locations and households search in different markets indexed by price and market tightness. In Huo and Rios-Rull (2015), we pose environments with competitive search leading to poorer households going to tighter but cheaper markets, which agrees with the evidence posted by Aguiar, Hurst, and Karabarbounis (2013) and Kaplan and Menzio (2013). Having competitive search in our model economies will be far costlier without, in all likelihood, changing the findings.

**Labor Market** Work is indivisible, and households are either employed or unemployed. The labor market has a search friction that we model by requiring firms to pay a hiring cost $\kappa$ per worker that they want to hire.[9] Denote by $V$ the measure of new jobs created in a given period. Newly hired employees are taken from the pool of the unemployed, which consists of workers of different skill levels $\epsilon$. Firms cannot discriminate in their search for workers by their skill level. Let $x_{\epsilon,1}$ denote the measure of employed workers of skill $\epsilon$ and $x_{\epsilon,0}$ the measure of unemployed workers of skill $\epsilon$; $x_0 = \sum_\epsilon x_{\epsilon,0}$ are all the unemployed and $x_1 = 1 - x_0$ the employed. Then, the probability of finding a job for a worker is $\frac{V}{x_0}$, while the expected skill level of a newly hired worker is $\sum_\epsilon \epsilon\, x_{\epsilon,0}$. While job finding rates do not not depend on the skill level, job losing rates do, with $\delta_n^\epsilon$ being the probability of job loss for an employed type $\epsilon$ worker.[10] We can construct a transition matrix for the employment status of a household that depends on endogenous variables and is given by

$$\Pi^w_{e'|e,\epsilon} = \begin{cases} 1-\delta_n^\epsilon & \text{if } e=1, e'=1 \\ \delta_n^\epsilon & \text{if } e=1, e'=0 \\ \frac{V}{x_u} & \text{if } e=0, e'=1 \\ 1-\frac{V}{x_u} & \text{if } e=0, e'=0 \end{cases} . \tag{3}$$

The average separation rate is $\overline{\delta}_n = \frac{\sum_\epsilon \delta_n^\epsilon\, x_{\epsilon,1}}{x_1}$. Households are paid a wage that is propositional to their skills. Let $w$ be the equilibrium price of one unit of skill.

### 2.1.1 Households

Households live forever and are indexed by their skills $\epsilon$, their employment status $e \in \{0,1\}$ and their assets, $a$.

**Endowment and labor market attachment** The skill level of a household is its amount of efficient units of labor $\epsilon$ that evolves according to a Markov process with exogenous transition matrix $\Pi^\epsilon_{\epsilon,\epsilon'}$. As stated, an employed worker loses a job at rate $\delta_n^\epsilon$ and finds a job at rate $\frac{V}{x_u}$, the latter being an equilibrium object. An employed household is paid $\epsilon\, w$; an unemployed household earns $\overline{w}$ units of the tradable good, the consumption equivalent of home production.

**Housing** Households like "houses", a good that exists in fixed supply and that has to owned in order to be enjoyed. No transaction costs are involved when changing the amount of housing in consecutive periods.

**Assets markets** A household can own housing and financial assets. At the beginning of the period we denote total household wealth by $a$, making the portfolio irrelevant given the absence of transaction costs. The rate of return of the financial asset depends on whether the household is a borrower or a saver. For reasons that will become

[9] Here, we follow Christiano, Eichenbaum, and Trabandt (2013) and Gertler and Trigari (2009).

[10] See Section 3 for a discussion of the reasons for this choice.

clear when we look outside steady-state allocations, we decompose the rate of return to financial assets, $b$, into two parts: $q(b)$ is determined today and applies to negative financial assets, and $R'(b)$ is determined tomorrow and applies to positive financial assets. Note that to emphasize the determination of the rate of return in the following period, we write it with primes even if we are looking at steady states. We have

$$q(b) = \begin{cases} 1, & \text{if } b \geq 0 \\ \frac{1}{1+r^*+\varsigma}, & \text{if } b < 0 \end{cases}, \qquad R'(b) = \begin{cases} 1+r', & \text{if } b \geq 0 \\ 1, & \text{if } b < 0 \end{cases}. \tag{4}$$

Here $r^*$ is the world interest rate and $\varsigma$ is a markup or transaction cost to borrowing. The rate of return to savings in the mutual fund is $r'$, which will be specified later. It is the return of a mutual fund that owns all the firms of the economy in addition to some foreign net asset position at fixed interest rate $r^*$. Obviously, in steady state, $r' = r^*$, and asset prices are constant, but we use $R'(b)$ and $r'$ to facilitate the exposition when we deal with the model economy outside the steady state.

There is also a collateral constraint. Negative financial assets can be held only if backed up by sufficient real assets. The ratio of debt to housing value can take a maximum value of $\lambda < 1$, which applies every period.

**Preferences** Households consume a certain number of varieties $\mathrm{I}_N$ and consume quantity $c_{N,i}$ of each variety $i \in [0, I_N]$. Note that different households choose different numbers of varieties, and the actual location of those varieties may differ. The utility flow from nontradables aggregates via a Dixit-Stiglitz type formulation, which in turn aggregates with the consumption of tradables $c_T$ yielding

$$c_A = c_A\left(c_N, c_T\right) = c_A\left(\int_0^{\mathrm{I}_N} \left(c_{N,i}\right)^{\frac{1}{\rho}} \quad di, c_T\right), \tag{5}$$

where $\rho > 1$ determines the substitutability among nontradable goods. We abuse notation by using $c_A$ and $c_N$ to refer both to the aggregates and to the aggregating function. Households also like housing $h$ and dislike shopping effort, $d$. We denote the period utility function by $u(c_A, h, d)$. In addition, the household discounts the future at rate $\beta$.

**Households' Problem** We are now in a position to write the household problem:

$$V(\epsilon, e, a) = \max_{\substack{c_{N,i}, c_T, \mathrm{I}_N, d \\ h, b, a'}} u(c_A, h, d) + \beta \sum_{\epsilon', e'} \Pi^w_{e'|e,\epsilon} \Pi^\epsilon_{\epsilon,\epsilon'} \; V(\epsilon', e', a'), \tag{6}$$

subject to the definition of the consumption aggregate (5) and

$$\int_0^{\mathrm{I}_N} p_i c_{N,i} + c_T + p_h\, h + q(b)\, b \;=\; a + 1_{e=1} w\, \epsilon + 1_{e=0}\, \overline{w} \tag{7}$$

$$\mathrm{I}_N \;=\; d\, \Psi^d(Q_g), \tag{8}$$

$$q(b)\, b \;\geq\; -\lambda\, p_h\, h, \tag{9}$$

$$a' \;=\; p_h'\, h + R(b)\, b. \tag{10}$$

Equation (7) is the household's budget constraint. Equation (8) is the requirement that varieties have to be found, which requires effort $d$ and depends on the tightness in the goods market. Equation (9) is the collateral requirement. Equation (10) describes the evolution of total wealth, which is the sum of the value of housing and the value of financial assets. Even though we are looking at steady states, we write the price of houses in the following period to be $p_h'$.

**Remark 1.** *We can take advantage of the properties of Dixit-Stiglitz aggregator. By defining*

$$c_N = \left(\frac{1}{\mathrm{I}_N}\int_0^{\mathrm{I}_N} c_{N,i}^{\frac{1}{\rho}}\right)^{\rho}, \qquad p = \left(\frac{1}{\mathrm{I}_N}\int_0^{\mathrm{I}_N} p_i^{\frac{1}{1-\rho}}\right)^{1-\rho}, \tag{11}$$

*we can obtain the standard demand function for each variety,*

$$c_{N,i} = \left(\frac{p_i}{p}\right)^{\frac{\rho}{1-\rho}} c_N. \tag{12}$$

*In equilibrium, all firms choose the same price, $p_i = p$, which allows us to rewrite expenditures on nontradables as $p\mathrm{I}_N c_N$ instead of $\int_0^{\mathrm{I}_N} p_i c_{N,i}$. Also, the first argument of the aggregating function $c_A$ collapses to $c_N\, \mathrm{I}_N^{\rho}$.*

Under equal pricing of all varieties, the first order conditions of the household problem are

$$u_{c_N} = p\, \mathrm{I}_N\, u_{c_T}, \tag{13}$$

$$u_{\mathrm{I}_N} = p\, c_N\, u_{c_T} - \frac{u_d}{\Psi^d(Q_g)}, \tag{14}$$

$$q(b) u_{c_T} = \quad R'(b)\, \beta \sum_{\epsilon',e'} \Pi^w_{e'|e,\epsilon} \Pi^{\epsilon}_{\epsilon,\epsilon'}\; u'_{c_T} + \zeta\, q(b), \tag{15}$$

$$p_h u_{c_T} = u_h + p_h'\, \beta \sum_{\epsilon',e'} \Pi^w_{e'|e,\epsilon} \Pi^{\epsilon}_{\epsilon,\epsilon'}\; u'_{c_T} + \zeta\, \lambda\, p_h. \tag{16}$$

Equation (13) shows the optimality condition between nontradable and tradable goods. Note that increasing the number of varieties results in additional shopping disutility, and equation (14) determines the optimal number of varieties. Equation (15) is the Euler equation with respect to the holding of financial assets, with $\zeta$ being the multiplier associated with the collateral constraint. When the collateral constraint is not binding, $\zeta = 0$. Equation

(16) is the Euler equation with respect to housing. When $\zeta > 0$, housing serves its additional role as collateral for borrowing.

**Representation of households** We describe the state of all households by means of a probability measure $x_{\epsilon,e}(a)$ defined over household type. Notice that we have already defined the marginals when we discussed the labor market, $x_{\epsilon,e} = \int_0^\infty x_{\epsilon,e}(da)$.

### 2.1.2 Firms in the Nontradable Goods Sector

Because of the existence of adjustment costs and hiring frictions, a firm producing variety $i$ is indexed by its capital stock $k$ and by its measure of workers $n = \{n_\epsilon\}$. The total labor input for a firm with employment $\{n_\epsilon\}$ is simply $\ell = \sum n_\epsilon \, \epsilon$.[11] Each firm owns a continuum of locations that have equal probability $\Psi^f(Q_g)$ of being visited by a household. Households demand different quantities of the good. To model how the firm is able to accommodate the delivery of big and small quantities of the good at different locations, we distinguish between three kinds of inputs. At each location, there is preinstalled or fixed capital $k$ and preinstalled labor $\ell_1$. There is also variable labor $\ell_2$ that can be dispatched to whatever locations need them after the consumer makes its order. The production function at each location is

$$F^N(k, \ell_1, \ell_2) = z_N \, k^{\alpha_0} \, \ell_1^{\alpha_1} \, \ell_2^{\alpha_2}, \tag{17}$$

where $z_N$ is just a units parameter. When a shopper wants to buy $c$ units of nontradables at a location, the amount of variable labor $\ell_2$ needed to produce $c$ is

$$g(c, k, \ell_1) = c^{\frac{1}{\alpha_2}} \, z_N^{\frac{-1}{\alpha_2}} \, k^{-\frac{\alpha_0}{\alpha_2}} \, \ell_1^{-\frac{\alpha_1}{\alpha_2}}. \tag{18}$$

At the posted price $p_i$, the demand schedule of a household of type $(\epsilon, e, a)$ is

$$c(\epsilon, e, a; p_i) = \left(\frac{p_i}{p}\right)^{\frac{\rho}{1-\rho}} c_N(\epsilon, e, a), \tag{19}$$

where $c_N(\epsilon, e, a)$ is the policy function derived from the household's problem. Applying the law of large numbers, the total variable labor that a firm needs when it has installed $k$ and $\ell_1$ in each of its locations is

$$\ell_2 = \Psi^f(Q^g) \int g[c(\epsilon, e, a; p_i), k, \ell_1] \, dx(\epsilon, e, a). \tag{20}$$

That firms have to preinstall capital and labor at a location no matter whether shoppers actually visit the location later is why demand can affect productivity: with a higher probability of being visited, more capital and labor can be used. The relative marginal productivity of preinstalled versus variable labor is the key margin that determines

[11] Again, because we will also look at non steady states, we keep track of the composition of the labor force. Otherwise, $\ell$ would have been a sufficient statistic for the firm.

how important the role of household demand is in determining output.

Firms have to choose labor one period in advance and incur hiring costs to do so. Both capital investment and hiring costs are in the form of tradable goods. The problem of the firms in the nontradable sector is then

$$\Omega^N(k,n) = \max_{\substack{i,v,k',n' \\ p_i,\ell_1,\ell_2}} \Psi^f(Q_g)p_i \int c(\epsilon,e,a;p_i)\,dx(\epsilon,e,a) - w\ell - i - \kappa v + \frac{\Omega^N(k',n')}{1+r^*}, \tag{21}$$

subject to

$$\ell_2 \geq \Psi^f(Q^g)\int g[c(\epsilon,e,a;p_i),k,\ell_1]\,dx, \tag{22}$$

$$\ell_1+\ell_2 = \sum n_\epsilon\,\epsilon \tag{23}$$

$$k' = (1-\delta_k)k + i - \phi^{N,k}(k,i), \tag{24}$$

$$n'_\epsilon = (1-\delta_n^\epsilon)n_\epsilon + v\,\frac{x_{\epsilon,0}}{x_0}, \tag{25}$$

where $\phi^{N,k}(k,i)$ is the capital adjustment cost, which slows down the adaptation process of firms to new circumstances. The first order conditions are

$$\frac{\ell_1}{\ell_2} = \frac{\alpha_1}{\alpha_2}, \tag{26}$$

$$\frac{1+r^*}{1-\phi_i^N} = -\frac{\alpha_2}{\rho}p_i'\Psi^f(Q^g)\int g_k[c(p_i,S,\epsilon,e,a),k',\ell_1']\,dx + \frac{1-\delta_k-(\phi_k^{N,k})'}{1-(\phi_i^{N,k})'}, \tag{27}$$

$$\kappa(1+r^*) = \frac{\alpha_2}{\rho}p_i' - w + (1-\overline{\delta}_n)\kappa. \tag{28}$$

Equation (26) is the optimality condition for the allocation of labor, which implies a constant ratio between pre-installed labor and labor that moves between locations. Equations (27) and (28) are the optimality conditions for investment and hiring.

**Remark 2.** *After some algebra, measured total factor productivity in the nontradable sector can be written as*

$$TFP^N = \frac{\int c(\epsilon,e,a;p_i)dx(\epsilon,e,a)}{k^{\alpha_0}(\ell_1+\ell_2)^{1-\alpha_0}} = z_N\left[\Psi^f(Q_g)\right]^{1-\alpha_2}\frac{\int c(\epsilon,e,a;p_i)dx(\epsilon,e,a)}{\left(\int[c(\epsilon,e,a;p_i)]^{\frac{1}{\alpha_2}}dx(\epsilon,e,a)\right)^{\alpha_2}}, \tag{29}$$

*which is increasing in the fraction of locations visited by shoppers.*

### 2.1.3 Firms in the Tradable Goods Sector

Firms in the tradable goods sector operate in a frictionless, perfectly competitive environment. To accommodate the possibility of decreasing returns to scale (a shorthand for limited comparative advantage), we pose that in addition to capital and labor, firms also need to use another factor, available in fixed supply, as an input of production.

Without loss of generality, we assume that there is one firm per unit of the fixed factor. Adjustment costs to expand capital and employment, given by functions $\phi^{T,k}(k,i)$ and $\phi^{T,n}(n',n)$, difficult a quick expansion of this sector. The problem of the firms is

$$\Omega^T(k,n) = \max_{i,v} \; F^T(k,\ell) - w\,\ell - i - \kappa\, v \; - \phi^{T,n}(n',n) + \frac{\Omega^T(k',n')}{1+r^*}, \tag{30}$$

subject to

$$\ell = \sum n_\epsilon\, \epsilon \tag{31}$$

$$k' = (1-\delta_k)k + i - \phi^{T,k}(k,i), \tag{32}$$

$$n'_\epsilon = (1-\delta_n^\epsilon)n_\epsilon + v\,\frac{x_{\epsilon,0}}{x_0}. \tag{33}$$

The first order conditions are

$$\frac{1+r^*}{1-\phi_i^{T,k}} = \left(F_k^T\right)' + \frac{1-\delta_k-(\phi_k^{T,k})'}{1-(\phi_i^{T,k})'}, \tag{34}$$

$$\left(\kappa + \phi_{n'}^{T,n}\right)(1+r^*) = \left(F_\ell^T\right)'\epsilon - w - (\phi_n^{T,n})' + (1-\overline{\delta}_n)\kappa, \tag{35}$$

which are similar to the optimality condition for nontradable firms.

**Mutual Fund** The mutual fund owns all tradable and nontradable firms, as well as the loans to homeowners. It also has an international asset position, which ensures the clearing of intertemporal savings. The steady-state rate of return of all these assets is the same, $r^*$. We assume a markup in the interest charged to the loan, $\varsigma$ per unit of borrowing, to cover costs.

The total amount of net financial assets in the economy is

$$L^+ = \int_{b>0} b(\epsilon,e,a)\; dx(\epsilon,e,a), \tag{36}$$

and the total amount of mortgages or loans in the economy is

$$L^- = -\int_{b<0} b(\epsilon,e,a)\; dx(\epsilon,e,a). \tag{37}$$

The net asset foreign position or holdings in international bond is

$$B = L^+ - \left(\Omega^N(K_N,N_N) - \pi^N(K_N,N_N)\right) - \left(\Omega^T(K_T,N_T) - \pi^T(K_T,N_T)\right) - \frac{1}{1+r^*}L^-. \tag{38}$$

All this gives an expression for the realized rate of return:

$$1 + r = \frac{\Omega^N(K_N, K_N) + \Omega^T(K_T, K_T) + (1 + r^*)B + L^-}{L^+}. \tag{39}$$

**Wage Determination** We assume an exogenous wage $w$ in steady state. Clearly, this is a ridiculous, albeit harmless, assumption. Essentially, given that there is no leisure in the utility function, the wage just determines the unemployment rate given the decreasing returns to scale nature of the technology. With labor market frictions, there is a wide range of wages that can be accepted by firms and households, as discussed in Hall (2005). The traditional way to determine the wage rate in a search model is to assume a Nash bargaining protocol between a representative worker and firm, as in Pissarides (1987) and Shimer (2005). In our model, the existence of two production sectors and heterogeneous workers significantly complicates the bargaining process.[12] Moroever, a bargaining process requires the establishment of exogenous bargaining weights, which is not too different from an exogenous wage. What is more interesting is how wages respond outside steady state; and we discuss that issue below.

**Steady-State Equilibrium** For a given world interest rate $r^*$ and exogenous wage $w$, a steady-state equilibrium is a set of decision rules and values for the households $(c_N, c_T, \mathrm{I}_N, d, b, h, a', V)$ as functions of individual state variables $(\epsilon, e, a)$; a set of decision rules and values for the nontradable firms $(k'_N, n'^{\epsilon}_N.i_N, v_N, \ell_1, \ell_2, p_i, \Omega^N)$ as functions of individual state variables $(n^{\epsilon}_N, k_N)$; a set of decision rules and values for the tradable firms $(k'_T, n^{\epsilon\prime}_T.i_T, v_T, \Omega^T)$ as functions of individual state variables $(n^{\epsilon}_T, k_T)$; aggregate employment in both sectors $N_N, N_T$; aggregate capital in both sectors $K_N, K_T$, the price of houses $p_h$, the goods market tightness $Q_g$, the measure of newly created jobs $\Phi^w$, and the measure over households' type $x$, such that

1. Given aggregates, households and firms solve their problems.

2. Aggregate variables are consistent with individual choices.

3. The housing market clears:
$$\int h(\epsilon, e, a)\, dx(\epsilon, e, a) = 1. \tag{40}$$

4. The measure of newly created jobs is consistent with firms' decision:

$$V = V_N + V_T. \tag{41}$$

[12] In Huo and Ríos-Rull (2013), the wage bargaining is to maximize the surplus of a weighted average of the workers and firms in two production sectors. In Krusell, Mukoyama, and Şahin (2010) and Nakajima (2012), a representative firm bargains with different workers separately, and households internalize the effect of additional saving on their bargaining position.

5. The goods market tightness is consistent with households' decision:

$$Q_g = \frac{1}{D} = \frac{1}{\int d(\epsilon, e, a)\, dx(\epsilon, e, a)}. \tag{42}$$

6. The return to financial assets as defined in equation (39) equals $r^*$.

7. The measure $x$ is stationary and is updated by households' choices and the process of the skill and employment shocks.

### 2.2 Out of Steady State: Transition

Studying behavior that is out of steady state involves two possibilities: to pose a truly stochastic process for shocks or to pose an unexpected shock (often referred to as an MIT shock) and then look for convergence to a new steady state. The former requires some form of approximating agents à la Krusell and Smith (1997); Krusell and Smith Jr. (1998), which in our economy is quite demanding because of the various market clearing prices. Because we are interested in the effects of a financial crisis, something that most people did not foresee, we think that the unexpected shock is an appropriate strategy to follow. To proceed, we need to specify the wage determination process, the only exogenous object posed in the steady state, as well as to extend the specification of the model to a nonstationary environment.

**The Financial Shocks** We explore the effects of a sudden worsening of the financial terms under which households have access to credit. We model this as an unforeseen but gradual change to the collateral constraint and to the borrowing cost (we also look at their separate effects). That is, starting from the steady state, the collateral constraint and the borrowing cost change unexpectedly. Households learn that there will be a new set of collateral constraint $\{\lambda_t\}$ and borrowing cost $\{\varsigma_t\}$ for $t \leq T$ which will stay at a constant value for $t > T$.

These changes affect the return to financial assets. For borrowers,

$$q_t(b) = \begin{cases} 1, & \text{if } b \geq 0 \\ \frac{1}{1+r^*+\varsigma_t}, & \text{if } b < 0 \end{cases}. \tag{43}$$

**Wage Determination** We follow Gornemann, Kuester, and Nakajima (2012) and assume that the wage rate is determined by the following expression:

$$\log w - \log \overline{w} = \varphi^w \left(\log Y - \log \overline{Y}\right), \tag{44}$$

where $\overline{w}$ and $\overline{Y}$ are the wage rate and output in steady state. In this formula, $\varphi^w$ measures the elasticity of wage rate with respect to output. We adopt this strategy because it provides an easy mechanism for replicating the behavior of wages in the data, as we will see below. Our approach avoids the issues discussed by Shimer (2005) and Hagedorn and Manovskii (2008).[13] It is also very easy to explore the implications of more or less flexible wages.

**Prices during the Transition** The sudden change in the financial terms faced by households has immediate implications for the value of firms, producing capital losses and reducing the instantaneous return of the mutual fund. After that period, firms have access to funds at the world interest rate, so the mutual fund's rate of return equals $r^*$ after the initial period. Note that mortgages do not change value, but installed capital does (because of the adjustment costs), as do the capitalized value of locations, the monopoly rents of varieties, and the fixed factor of the tradable producers.

To see more clearly how $r_t$ evolves, we write the rate of return of savings as

$$1 + r_t = \frac{\Omega_t^N(K_{N,t}, K_{N,t}) + \Omega_t^T(K_{T,t}, K_{T,t}) + (1 + r^*)B_{t-1} + L_{t-1}^-}{L_{t-1}^+}. \tag{45}$$

After the financial shock, firms' equity value shrinks, and the return to saving $r_0$ is less than the expected steady state return $r^*$ and the savers bear the capital loss. Mortgage holders suffer because their assets (houses) see their value reduced, but not the value of the liabilities because of the lack of bankruptcies or foreclosures. After the initial period, the rate of return of the mutual fund reverts to $r^*$.

Along the transition, various prices have to be determined: the housing market has to clear, yielding $p_{h,t}$, the price of nontradables has to be set by the monopolistic competitive firms, and the wage has to be determined because it is a function of output, which is itself an endogenous variable (see equation (44)).

**The Household Problem** During the transition, the household problem is

$$V_t(\epsilon, e, a) = \max_{\substack{c_{N,i}, c_T, \mathrm{I}_N, d \\ h, b, a'}} u(c_A, h, d) + \beta \sum_{\epsilon', e'} \Pi^w_{e'|e,\epsilon,t} \Pi^\epsilon_{\epsilon,\epsilon'} \; V_{t+1}(\epsilon', e', a'), \tag{46}$$

[13] A more modern approach is that of Christiano, Eichenbaum, and Trabandt (2013), which estimates the details of the bargaining protocols by targeting the response of wages. It should give a response that is similar to our approach, even if theirs is more theoretically sound.

subject to

$$p_t \mathrm{I}_N c_N + c_T + p_{h,t} h + q_t(b) b = a + 1_{e=1} w_t \epsilon + 1_{e=0}\, \overline{w} \tag{47}$$

$$\mathrm{I}_N = d\ \Psi^d(Q_{g,t}), \tag{48}$$

$$a' = p_{h,t+1} h + R_{t+1}(b) b, \tag{49}$$

$$q_t(b) b \geq -\lambda_t p_{h,t} h, \tag{50}$$

with $V_t \to V^1$ as $t \to \infty$, where $V^1$ is the value function in the steady state of the exogenous variables after the shocks. In the same fashion, all prices and aggregates also converge to the steady-state values of the economy with the financial variables $\lambda$ and $\varsigma$ set to their final values. The two types of firms face similar problems during the transition.

**Computation of the Transition** The transition requires the computation of the initial and final steady states. Then we assume that the transition lasts for $T$ periods (350 in our case). Given a set of (350) wages and prices for houses and for nontradables, followed by the final steady state wage and prices we solve the problem of the agents and given the initial distribution we compute the set of (350) wages and prices what would clear market equilibrium. A fixed point of this process is the transition.

**Properties of the Allocation along the Transition** Note that the tightening of the collateral constraint induces in many households a reduction either in consumption or in housing (or both). In fact, all households reduce their consumption of tradables because of a precautionary motive. The reduction in demand for nontradables reduces their prices, which in turn reduces the wealth of all households, further reducing their consumption. Another property to note is that in the final stage of the transition, households will be wealthier because of the precautionary motive, and therefore consumption will be higher.

## 3 Mapping the Model to Data

We start by discussing some details of national accounting, describing how the variables in the model correspond to those measured in the National Income and Product Accounts (NIPA) (Section 3.1). We then discuss the functional forms used and the parameters involved (Section 3.2), and we set the targets that the model economy has to satisfy (Section 3.3). We then discuss how to set the parameters that do not affect the steady state but have dynamic implications (Section 3.4), and we finish with a description of what we mean by a financial shock (Section 3.5).

### 3.1 NIPA and Measured Total Factor Productivity

Output measured in terms of the numeraire in base year prices is given by[14]

$$Y_t = p^* Y_{N,t} + Y_{T,t}, \tag{51}$$

where the nontradable goods output $Y_{N,t}$ is given by

$$Y_{N,t} = \Psi^f(Q_{g,t}) \int c_{N,t}(\epsilon, e, a)\ dx_t(\epsilon, e, a), \tag{52}$$

and the tradable goods output $Y_{T,t}$ is given by

$$Y_{T,t} = F^T(K_{T,t}, N_{T,t}). \tag{53}$$

The GDP deflator in our economy is

$$\overline{P}_t = \frac{Y_{N,t}}{Y_t} p_t + \frac{Y_{T,t}}{Y_t}. \tag{54}$$

To construct aggregate measures of factors, we use total employment $N_t = N_{N,t} + N_{T,t}$, total capital as $K_t = K_{N,t} + K_{T,t}$, and total labor input as the product of employment and the average efficiency units of employed workers $L_t = \sum_\epsilon x_{\epsilon,1,t}\ \epsilon$. We construct two different measures of factor productivity. One uses efficient labor and the other total employment, yielding

$$Z_t^1 = \frac{Y_t}{K_t^{1-\upsilon} L_t^{\upsilon}}, \tag{55}$$

$$Z_t^2 = \frac{Y_t}{K_t^{1-\upsilon} N_t^{\upsilon}}, \tag{56}$$

where $\upsilon$ is the steady-state labor share.

When the quality of the labor force is constant these two measures of TFP display the same patterns. However, in our model, the quality of the labor force is countercyclical, making these two measures different.

### 3.2 Functional Forms and Parameters

**Preferences (11)** We adopt GHH-type (Greenwood, Hercowitz, and Huffman (1988)) preferences between consumption and shopping effort. These preferences guarantee that the quantity consumed per variety and the number of varieties move together as a function of income, which in turn makes measured TFP procyclical. The period

[14] Notice that adjustment costs are internal to the firm and hence are not part of GDP. In any case, they are too small to make any measurable difference.

utility function is separable between consumption and housing services and is given by

$$u(c_A, d, h) = \frac{1}{1-\sigma_c}\left(c_A - \xi_d \frac{d^{1+\gamma}}{1+\gamma}\right)^{1-\sigma_c} + v(h). \tag{57}$$

Tradables and nontradables are combined into $c_A$, via an Armington aggregator:

$$c_A = \left(\omega\left[\int_0^{\mathrm{I}_N} c_{N,i}^{\frac{1}{\rho}}\ di\right]^{\frac{\rho(\eta-1)}{\eta}} + (1-\omega)c_T^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}. \tag{58}$$

The preference parameters include the discount factor, $\beta$, the risk aversion parameter for consumption, $\sigma_c$, the parameter that determines average shopping effort, $\xi_d$, the elasticity of substitution between tradable and nontradable goods, $\eta$, the parameter that determines the elasticity of substitution among nontradables, $\rho$, and the home bias parameter, $\omega$.

The utility function for housing services $v(h)$ is more involved. As discussed earlier, to match the cross-sectional housing value distribution, the marginal utility of housing has to decrease more quickly for rich households. In other words, Engel curves between housing and nonhousing for high income levels should be nonlinear. This feature prevents rich households from buying and enjoying a lot of housing after the finance shock. With linear Engel curves, the price of housing would barely move.[15] We pose a nonbinding satiation point in housing and three different regions with increasing curvature. Specifically, we have

$$v(h) = \begin{cases} \xi_h \log h, & \text{if } h < \widehat{h}_1 \\ \frac{\xi_h}{1-\sigma_h}\left(h + \xi_h^1\right)^{1-\sigma_h} + \xi_h^2, & \text{if } \widehat{h}_1 \leq h \leq \widehat{h}_2 \\ \xi_h^3\sqrt{\overline{h}^2 - (\overline{h}-h)^2} + \xi_h^4, & \text{if } h > \widehat{h}_2. \end{cases} \tag{59}$$

Although this function looks like it has many parameters, $\{\xi_h^1, \xi_h^2, \xi_h^3, \xi_h^4\}$ are chosen to ensure that the function is continuously differentiable. Still, five parameters are left: $\xi_h, \widehat{h}_1, \widehat{h}_2, \sigma_h$, and $\overline{h}$. The latter is set to be large enough to have no agents in its neighborhood. The other four are set in the calibration stage.

**Process for Skills and Employment (19)** We pose a four-state Markov chain for skills and skill-specific job losing rates.

**Production Technology (7)** The production functions of tradables and nontradables are both Cobb-Douglas: $F^N(k, \ell_1, \ell_2) = z_N\ k^{\alpha_0}\ \ell_1^{\alpha_1}\ \ell_2^{\alpha_2}$ and $F^T(k, n) = z_T\ k^{\theta_0} n^{\theta_1}$.

[15] A possible solution to this problem is to have segmented markets à la Ortalo-Magne and Rady (2006) or Ríos-Rull and Sánchez-Marcos (2008a), which would have dramatically increased the computational burden of the project.

Table 1: Exogenously Determined Parameters

| Parameter | Value |
|---|---|
| Risk aversion for consumption, $\sigma_c$ | 2.0 |
| Satiation level for housing, $\overline{h}$ | 5.0 |
| Curvature of shopping disutility, $\gamma$ | 1.5 |
| Elasticity of substitution bw tradables and nontradables, $\eta$ | 0.80 |
| Price markup, $\rho$ | 1.1 |
| Loan-to-value ratio, $\lambda$ | 0.80 |
| Interest rate for international bonds, $r^*$ | 4% |

**Adjustment Costs (3)** Capital adjustment costs affect both sectors equally and are given by $\phi^k(k^j, i^j) = \frac{\psi^k}{2}\left(\frac{i^j}{k^j} - \delta_k\right)^2 k^j$, for $j \in \{T, N\}$, where $\delta_k$, the capital depreciation rate, and $\varphi^k$, the size of the adjustment cost, have to be set. In addition to the capital adjustment cost, the tradable sector also has labor adjustment costs, which are given by an expression very similar to that of capital,[16] $\phi^{T,n}(n', n) = \frac{\psi^n}{2}\left(\frac{n'}{n} - 1\right)^2 n$.

**Matching in the Goods Market (2)** The matching technology in the nontradable goods market is

$$M(D, T) = \nu D^{\mu} T^{1-\mu}, \tag{60}$$

where $\mu$ determines the elasticity of the matching probability with respect to market tightness and $\nu$ is the matching efficiency.

### 3.3 Targets and Values

The model period is half a quarter, shorter than the standard quarter because the minimum unemployment length is one period and we want to match the U.S. average duration.

We separate the parameters into three groups: the first group includes the parameters that we set exogenously (see Table 1). In the second group (shown in Tables 2 and 3), the parameters are jointly determined by solving a large system of equations that equate model statistics in the steady state with targets based on U.S. data.[17] The parameters in the third group have no bearing on the steady state and are determined to match certain targets in the transition experiments. All parameters are described in annual terms unless otherwise specified .

[16] The differences are minute and have to do with the fact that investment itself includes the transaction costs, which in the worse case implies about a difference of 0.2%. We write them differently to avoid the cumbersome notation of the expression for the attrition rate of employment that varies slightly with the skill composition of employment.

[17] This second group is the set of calibrated parameters or exactly identified generalized method of moments (GMM) estimated parameters.

**Exogenous Parameters** We set the risk aversion for consumption to 2.[18] We set the satiation point of housing holding to be $\overline{h} = 5$ (in the calibrated economy, the 99th percentile has 4.8 units of housing and the household 99.9, 4.9). We choose a curvature of the searching disutility, $\frac{1}{\gamma} = 0.67$, in order to have a value that is consistent with the Frisch elasticity of labor.[19] To determine the elasticity of substitution between market goods and numeraire goods, we follow the trade literature on the elasticity of substitution between nontradable goods and tradable goods. We choose the benchmark value used in Bianchi (2011), 0.80, which is also similar to the estimate in Heathcote and Perri (2002). The price markup $\rho$ reflects the substitutability among the nontradable goods as well as the price markup set by the monopolistic firms. In the literature, there is no solid evidence on how large this parameter should be. Basu and Fernald (1997), using micro reasoning, claim that the implied markup is not significantly greater than 1, whereas Christiano, Eichenbaum, and Evans (2005) estimate the price markup using macro data and obtain a value ranging from 1.01 to 1.85. We have set $\rho = 1.1$. We choose the maximum loan-to-value ratio $\lambda$ to be 0.80, which implies a 20% down payment ratio. Clearly, larger loans-to-value ratios were the norm in the years before the financial crisis. Our choice is guided by the requirement that the crisis leaves nobody with an empty budget set, whereas still have a sensible reduction in the price of housing. This is because in our economy there is no default, so housing price drops are limited by the minimum equity and the meager earnings of the unemployed houses. Below we will discuss bankruptcy. The risk-free rate of return is 4%.

Other parameters are also set exogenously but depend on the calibrated parameters, and we discuss them below. They essentially amount to symmetry requirements to reduce the set of targets.

**Calibrated Parameters** The parameters in the second set are jointly determined by matching steady-state moments with corresponding targets, as shown in Table 2. We split these targets into those related to aggregate macroeconomic moments, those related to cross-sectional moments, and those associated with the determination of units. We associate one parameter with each target, and since the parameters are jointly determined, this association is just heuristic. Nevertheless, we find it useful for understanding the workings of the model. Table 2 shows targets and parameters. Some of those parameters have economic meaning, others are just the determinants of units. Accordingly, the table separates these two blocks.

In terms of households' balance sheets, we target the wealth-to-output ratio to be 4.0, the housing-value-to-output ratio to be 1.7 and the debt-to-output ratio to be 0.4. These targets match the U.S. data between 2004 and 2007 (calculated from the Flow of Funds; see Appendix A for a detailed description of the data). Turning to the production side, we target tradable output to be 30% of total output, the capital-to-output ratio to be 2, and the labor share in both sectors to be 0.64. We assume a constants returns to scale production function in the nontradable goods sector, but a decreasing returns to scale production function in the tradable goods sector to

[18]It is the risk aversion of the consumption aggregate net of search effort.

[19]This is another irrelevant parameter. What matters here is the disutility level parameter $\xi_d$ and the compounded effect of the search disutility curvature $\gamma$ and the matching technology elasticity $\mu$. In fact, with random search the effect of these two cannot be separated. Parameters $\xi_d$ and $\mu$ are set at the calibration stage.

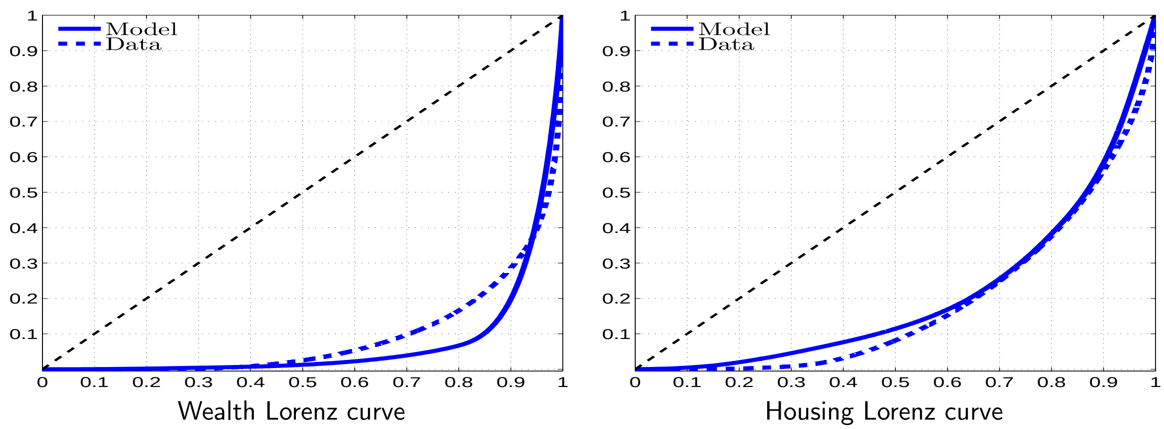
prevent the tradable sector from expanding too quickly in the transition. We target a 6% unemployment rate. The literature has few direct estimates of the vacancy cost. Silva and Toledo (2009) report the flow vacancy costs to be 4.3% of the quarterly wage and the training costs to be 55% of the quarterly wage. Hagedorn and Manovskii (2008) and Shimer (2012) have a smaller vacancy cost estimate. We target a vacancy-cost-to-output ratio of 0.02, which lies in between these estimates. Regarding unemployed workers, we target the ratio of the value of home production to the lowest earnings to 0.5. For the nontradable goods sector, we target a capacity utilization of 81%, which is the average of the official data series from Corrado and Mattey (1997). To set the cutoff values and the curvature for the housing utility function, we choose $\widehat{h}_1$, $\widehat{h}_2$, and $\sigma_h$ to match the U.S. housing Lorenz curve. To determine units, we normalize total output, the nontradable goods price, and goods market tightness to 1.

Table 2: Endogenously Determined Parameters: Aggregate

| Target | Data | Model | Parameter | Value |
|---|---|---|---|---|
| ***Aggregate Targets*** | | | | |
| Share of tradables | 0.30 | 0.30 | $\omega$ | 0.98 |
| Occupancy rate | 0.81 | 0.30 | $\nu$ | 0.81 |
| Capital-to-output ratio | 2.00 | 2.00 | $\delta_k$ | 0.01 |
| Labor share in nontradables | 0.64 | 0.64 | $\alpha_0$ | 0.27 |
| Symmetry of labor coeff. in nontradables | $\alpha_1 = \alpha_2$ | | $\alpha_1$ | 0.36 |
| Labor share in tradables | 0.64 | 0.64 | $\theta_1$ | 0.66 |
| Vacancy-cost-to-output ratio | 0.02 | 0.02 | $\kappa$ | 0.42 |
| Home-production-to-lowest-earning ratio | 0.50 | 0.50 | $\overline{w}$ | 0.07 |
| Wealth-to-output ratio | 4.00 | 4.02 | $\beta$ | 0.97 |
| Housing-value-to-output ratio | 1.70 | 1.70 | $\xi_h$ | 0.54 |
| Unemployment rate | 6.00 | 6.00 | w | 0.68 |
| ***Cross-Sectional Targets*** | | | | |
| Fraction of housing held by bottom 70% | 0.25 | 0.25 | $\widehat{h}_1$ | 1.48 |
| Fraction of housing held by bottom 80% | 0.39 | 0.39 | $\widehat{h}_2$ | 4.22 |
| Fraction of housing held by bottom 90% | 0.58 | 0.58 | $\sigma_h$ | 2.92 |
| ***Units Targets*** | | | | |
| Output | 1.00 | 1.00 | $z_N$ | 0.93 |
| Relative price of nontradables | 1.00 | 1.00 | $z_T$ | 0.48 |
| Market tightness in goods markets | 1.00 | 1.00 | $\xi_d$ | 0.03 |

We calibrate the endowment process to capture the earnings and wealth distribution in the United States, and the related parameters are shown in Table 3 and 4. We use four discrete endowment levels, that is, $\epsilon \in \{\epsilon_1, \epsilon_2, \epsilon_3, \epsilon_4\}$. We interpret the first three endowments as earnings for the majority of households. The fourth endowment level is intended to capture the superrich households in the economy, as in Castañeda, Díaz-Giménez, and Ríos-Rull (2003) or Díaz, Pijoan-Mas, and Ríos-Rull (2003). The transition probability and the levels of the first three states are calibrated to approximate an AR(1) process using the method by Tauchen (1986). Following Nakajima (2012) and Domeij and Heathcote (2004), we set the persistence of the endowment process to 0.91 and the standard deviation of the innovation term to 0.20. We assume the first three types of households have the same probability of becoming type 4 households who are superrich, $\pi_{entry} = \Pi^{\epsilon}_{i,4}$, $i \in \{1, 2, 3\}$, and that type 4 households return to one of the first three states with the same probability $\pi_{exit} = \Pi^{\epsilon}_{4,i}$, $i \in \{1, 2, 3\}$. We calibrate the rest of the parameters to match the earning Gini index, 0.64 and the wealth Gini index, 0.82 (calculated from 2007 SCF data). Figure 2 shows the comparison of the net worth and housing Lorenz curve between our model and the U.S. economy.

Figure 2: Cross-Sectional Distribution




As shown by Fang and Nie (2013) and Lifschitz, Setty, and Yedid-Levi (2015), different education groups have job finding rates similar to each other, but the job separation rate is substantially larger for low educated workers. Accordingly, we choose the separation rate for type 1 workers to target an average job duration of 1.5 years and the separation rate for type 3 and type 4 workers to target an average job duration of 5 years. The job separation rate for type 2 workers is set to match the total unemployment rate, which implies a 2.5 year job duration.

### 3.4 Dynamic Parameters

The parameters in the last group (shown in Table 5) have no steady-state implications, and we set them according to their dynamic implications.

**Wage Equation** Recall our following wage rule:

$$\log \frac{w_t}{P_t} - \log \frac{w}{P} = \varphi^w \left(\log Y_t - \log Y\right). \tag{61}$$

Table 3: Parameters Related to the Endowment Process in the Baseline Economy

| Parameter | Value | Target | Value | Model |
|---|---|---|---|---|
| $\delta_n^1$ | 0.083 | Job duration for type 1 | 1.5 year | 1.5 year |
| $\delta_n^3$ | 0.025 | Job duration for type 3 | 5 year | 5 year |
| $\delta_n^4$ | 0.025 | Job duration for type 4 | 5 year | 5 year |
| $\epsilon_4$ | 37.41 | Debt to output ratio | 0.40 | 0.40 |
| $\epsilon_1$ | 0.169 | Average skill level | 1.00 | 1.00 |
| $\Pi_{1,4}^\epsilon$ | 0.002 | Income Gini index | 0.64 | 0.65 |
| $\Pi_{4,1}^\epsilon$ | 0.011 | Wealth Gini index | 0.82 | 0.84 |
| $\Pi_{1,1}^\epsilon$ | 0.964 | Persistence, $\rho_s$ | 0.91 | 0.91 |
| $\Pi_{2,2}^\epsilon$ | 0.976 | St.d of innovation, $\sigma_s$ | 0.20 | 0.20 |

Table 4: Parameters Related to the Endowment Process in the Baseline Economy

| Parameter | Value | Target | Parameter | Value | Target |
|---|---|---|---|---|---|
| $\Pi_{3,3}^\epsilon$ | 0.964 | $\sum_{i=1}^3 \Pi_{3,i} = 1 - \Pi_{1,4}$ | $\Pi_{2,4}^\epsilon$ | 0.002 | $\Pi_{2,4} = \Pi_{1,4}$ |
| $\Pi_{3,2}^\epsilon$ | 0.033 | Tauchen (1986) method | $\Pi_{3,4}^\epsilon$ | 0.002 | $\Pi_{3,4} = \Pi_{1,4}$ |
| $\Pi_{1,2}^\epsilon$ | 0.033 | $\Pi_{1,2} = \Pi_{3,2}$ | $\Pi_{4,2}^\epsilon$ | 0.011 | $\Pi_{4,2} = \Pi_{4,1}$ |
| $\Pi_{1,3}^\epsilon$ | 0.000 | $\sum_{i=1}^3 \Pi_{1,i} = 1 - \Pi_{1,4}$ | $\Pi_{4,3}^\epsilon$ | 0.011 | $\Pi_{4,3} = \Pi_{4,1}$ |
| $\Pi_{2,1}^\epsilon$ | 0.011 | $\Pi_{2,1} = \Pi_{2,3}$ | $\Pi_{4,4}^\epsilon$ | 0.967 | $\sum_{i=1}^4 \Pi_{4,i} = 1$ |
| $\Pi_{2,3}^\epsilon$ | 0.011 | $\sum_{i=1}^3 \Pi_{2,i} = 1 - \Pi_{1,4}$ | $\epsilon_2$ | 0.423 | $\log y_{s,2} = 0.5(\log y_{s,3} + \log y_{s,1})$ |
| $\Pi_{3,1}^\epsilon$ | 0.000 | $\Pi_{3,1} = \Pi_{1,3}$ | $\epsilon_3$ | 1.059 | $\log y_{s,3} - \log y_{s,1} = 2\sigma_y$ |

Figure 3 displays the paths for (detrended) output, wages, and the forecasted wages based on different values of $\varphi^w$. The best fit between the actual and the forecasted wage series occurs at an approximated value of $\varphi^w = 0.55$.[20]

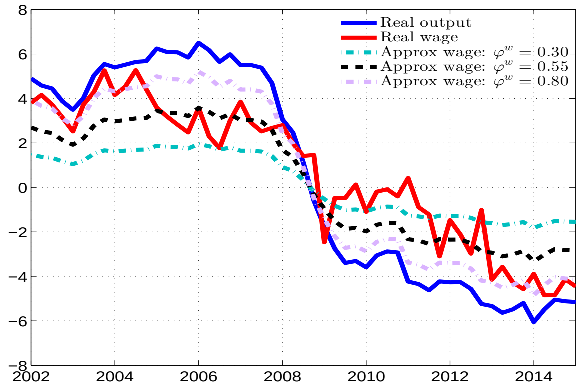
**Adjustment Costs** In our model, $\psi^k$ and $\psi^n$ determine how fast the economy can reallocate resources across sectors and over time. In the baseline model, we set $\psi^k = \psi^n$, and we choose a value of 1.57 to match the 30% drop in investment during the Great Recession. By doing this, we impose the drop in investment. Recall that the important objective of this paper is to explore what can generate a drop in consumption.

**Decreasing Returns to Scale in Tradables** The share of income from the tradable sector that does not go to labor can be due to either capital or the fixed factor. We have chosen the size of the fixed factor (the degree of decreasing returns) to limit the expansion of nontradables after the financial shock to 4%, capturing a notion of limited comparative advantage (see Alessandria, Pratap, and Yue (2013)). This implies a value of $\theta_0 = .21$.[21]

[20] This value is similar to that used in Gornemann, Kuester, and Nakajima (2012) and Hagedorn and Manovskii (2008).

[21] In this case, the steady state changes when this variable changes. We proceeded by the guess and verify method, fixing this variable, recalibrating all the other parameters to attain the desired steady state, and verifying that nontradables expand the desired amount.

Figure 3: Comparison between Real Wage and Approximated Wage




Note: Real output and real wage are linearly detrended from 1990:I to 2015:II.

Table 5: Dynamically Calibrated Parameters

| Parameter | Value | Target |
|---|---|---|
| Adjustment cost, $\psi$ | 1.57 | Investment declines by 30% |
| Decreasing returns to scale in tradables, $\theta_0$ | 0.21 | Tradables to output ratio increases by 4% |
| Wage elasticity, $\varphi^w$ | 0.55 | Ratio of wage change to output change, 0.45 |
| Matching elasticity in goods market, $\mu$ | 0.80 | TFP declines by 1.5% |

Still, our model economy dramatically exaggerates the increase in exports. Note that 30% of output is tradable, and even if it is difficult to quickly expand this sector, all the tradable consumption and all the investment can automatically be exported without any cost. As a result, exports expand tremendously in the recession. The adjustment costs only partially limit the additional expansion of exports.

**Matching Elasticity in the Nontradable Goods Market** The magnitude of the change in TFP in our model is mainly determined by the search frictions in the goods market. If $\mu = 0$, then firms will meet their customers at a constant rate and TFP would be constant over the cycle. For $\mu > 0$, TFP responds to variations in the search effort of households. We choose $\mu$ to generate the observed reduction in TFP in the United States during the Great Recession. This parameter and the shopping elasticity in preferences cannot be identified separately with aggregate data, but their joint effect can be measured from the response of TFP.

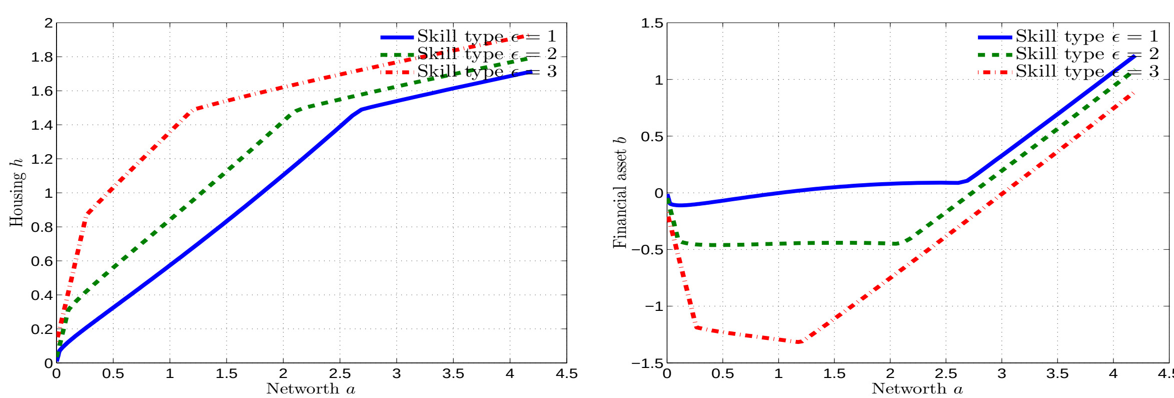
### 3.5 The financial shocks

The last thing to set is the magnitude of the financial shock. One possible strategy would be to choose the financial shock so that the model generates the observed drop in housing prices, which is about 25%. Such a strategy would pose in our model that some households have an empty budget set leaving bankruptcy as their only choice. We do not want to have unexpected bankruptcies in the baseline economy (in Section 6.1 we extend the model to incorporate a form of default, and then we do target the price drop). We, therefore, explore the effects of a financial shock that generates a price drop that is consistent with the model in the sense that no agent ends up with an empty set. Such a price drop is about 18%, or 72% of that in the data. The shock takes the form of both an increase in the down payment from 20% to 40% (a reduction of the loan-to-value ratio from 80% to 60%) and an increase in the interest rate markup of 50 basis points annually (from zero to 50).

## 4 Steady-State Analysis: Long Term Implications of Financial Shocks

We start by analyzing households' choices of housing and financial assets. Figure 4 displays the policy functions for employed workers with skill type 1 to 3 in the baseline economy, ignoring the very rich, who are essentially to the right of the figure. Each household skill type has three wealth ranges. The poorest households are those for whom the housing function has very steep upward segments and the financial assets function has downward segments. The collateral constraint for these households is binding and does not satisfy the static Euler equation between housing and consumption: the households would like to enjoy more housing but cannot because of the binding constraint. The next wealth type goes from minimum financial wealth to zero financial wealth. These households have debt, so they are leveraged (more than 100% of their wealth is in housing), but they have the amount of housing that they want and the collateral constraint is not binding for them. Finally, the last wealth group has positive financial assets. Those households are the ones that own all firms, and all mortgages and have some foreign asset position.

Figure 4: Policy Function for Housing and Financial Assets in the Baseline Economy




In Bewley-Imrohoroglu-Huggett-Aiyagari type incomplete market economies, an increase in frictions typically translates into more steady-state wealth because households want a higher wealth-to-income ratio to bear the increased difficulties posed by more frictions. In our economy, the higher loan-to-value ratio unambiguously increases total steady-state wealth. The effect of the markup shock is less clear because it increases the user cost of housing for borrowers, and hence it may reduce the rationale for holding wealth. Overall, though, as Table 6 shows, there is a small increase in total wealth despite having a decline in housing wealth (due to lower housing prices) in the new steady state. Given the constant world interest rate and the small appreciation in the stock market, this is achieved via an improvement in the net foreign asset position. The increase in wealth, the reduction in the housing prices and the tighter loan to value ratio all contribute to reduce the indebtedness of households that falls in the range of 30% to a bit above one-quarter of GDP.

Table 6: Percentage Differences between the Steady State before and after the Shocks

| | Both Shocks | $\lambda$ shock | $\varsigma$ shock |
|---|---|---|---|
| ***Differences in Assets and Debts Relative to GDP*** | | | |
| Net wealth | 5.88 | 4.38 | 1.50 |
| Housing wealth | -16.50 | -9.37 | -10.25 |
| Stock market | 2.75 | 2.00 | 1.12 |
| Net foreign asset position | 19.50 | 11.60 | 10.90 |
| Debt | -13.14 | -8.51 | -6.94 |
| ***NIPA Related*** | | | |
| Output | 0.90 | 0.68 | 0.33 |
| Employment | 0.60 | 0.46 | 0.22 |
| Consumption | 1.88 | 1.40 | 0.73 |
| Investment | 0.77 | 0.56 | 0.31 |
| Nontradable output | 1.89 | 1.41 | 0.73 |
| Tradable output | -1.43 | -1.00 | -0.62 |
| ***TFP Related and House Prices*** | | | |
| TFP | 0.24 | 0.19 | 0.08 |
| Labor productivity | 0.30 | 0.23 | 0.11 |
| Labor quality | -0.19 | -0.15 | -0.07 |
| Search effort | 1.00 | 0.79 | 0.34 |
| Housing prices | -9.71 | -5.48 | -6.07 |

The higher wealth of households translates into higher GDP via an increase in consumption (note that most of consumption consists of nontradables that cannot be imported). Investment and employment also rise to maintain the higher output of nontradables. There is an increase in productivity generated by the higher search effort of households who now consume more varieties. The total effect is 0.24% higher productivity.

The effects on output and employment of the shock to the loan-to-value ratio ($\lambda$ shock) are twice as big than those of the loan markup shock ($\varsigma$ shock). This is mainly because the reduction in loan-to-value ratio greatly increases the saving motive of households leading to a higher wealth level and a higher production capacity in the nontradable sector. On the other hand, the effects of the borrowing markup shock on the price of houses are slightly larger than those of the loan-to-value ratio shock. This is because the markup shock increases directly the user cost of houses for all borrowers, which reduces housing demand.

## 5 Exploring the Effects of the Financial Shock

Although the long-term effects of the financial shock are to increase wealth, output, and consumption, the transition involves a recession. Asset prices respond immediately to the new credit conditions; that is, on impact house prices go dow,n producing an instantaneous reduction in wealth arising only from lower prices (neither houses, capital, nor the ability to collect rents is destroyed). The asset price amplification of the financial shock is similar to that discussed inKiyotaki and Moore (1997). There is no reduction in the production possibilities of the economy, nor is there a switch of equilibria.

In response to the tighter financial conditions, households dramatically reduce their housing demand and increase their savings. Both processes feed into each other: as lower housing demand reduces house prices, which in turn increases savings, which lowers output. Households reduce consumption, which consists mostly of nontradables. This sector then suffers a reduction in productivity and profits, which reduces employment. Households want to allocate resources to the production of tradables to increase net exports and accumulate the necessary wealth, but the adjustment costs and decreasing returns to scale makes this process difficult. The reduction in the consumption of nontradables occurs immediately, whereas the increase in the production of tradables takes time. All of these effects create the recession.

We now look in detail at the direct effects of the financial shock by examining the transition of the aggregates in our main experiment (Section 5.1). To better understand the role played by each part of our model economy, we start by looking separately at the following: the two items in the financial shock (Section 5.2); the contribution to the the drop in housing prices to the recession (Section 5.3); the role of the real frictions that prevent the economy from reallocating fast factors of production from the nontradable sector to the tradable sector (Section 5.4); the role of endogenous productivity (Section 5.5); and the role of wage rigidity (Section 5.6).

### 5.1 The Main Experiment

The main experiment poses a two-pronged financial shock. The loan-to-value ratio increases in three equal steps over 3 months (this helps to prevent households from having an empty budget set), and the interest rate of loans experiences an increase of 50 basis points. The increase in the loan-to-value ratio makes many households—those whose collateral constraint was initially binding or close to being binding—incapable of maintaining the same size house as before, inducing them to sell. Further, the increased interest rate makes houses less attractive for many borrowers who will also reduce their housing holdings. All these factors push house prices downwards, further amplifying the effects of the financial shock. For all the households who were initially away from the collateral binding region, there is also an incentive to increase savings because the tightened borrowing capability and higher unemployment risk during the transition push up the optimal saving-to-income ratio. The contribution of the increased markup on the interest in loans is to make housing less attractive for borrowers by increasing its user cost, also contributing to the decline in house prices and the increase in savings.

The sudden loss of wealth and its associated desire to increase savings depresses the consumption of both tradables and nontradables. Tradables can easily be exported in this economy, but lower consumption of nontradables reduces their producers' profits via a decrease in both the probability of selling and in their price. In response, firms that produce nontradable cut their investment and hiring, leading to higher unemployment and lower output. Lower unemployment decreases the job finding rate, further tightening households' budget constraint and strengthening their saving motive, which further increases the downward pressure on firms' profits. Firms in the tradable goods sector benefit from the recession: neither their price nor their productivity is affected, but their labor costs decrease because of the reduction in wages during the recession. Consequently, these firms expand, but because of their adjustment costs, they do so slowly, and because of the decreasing returns to scale, their expansion is limited. The inability of the tradable to sector to expand quickly is a necessary condition for the recession.

Table 7: Changes in Aggregate Variables during the Transition

| | Main Exp. | Separate Shocks | | Const-Hous | Other Experiments | | |
|---|---|---|---|---|---|---|---|
| | Both Items | Down Paym | $r$ markup | Prices | High $\varphi^w$ flex wage | Low $\psi$ no adj-cost | Low $\mu$ const-TFP |
| ***NIPA Related*** | | | | | | | |
| Output | -3.47 | -2.22 | -1.60 | -0.32 | -2.80 | -2.44 | -1.51 |
| Employment | 8.83 | 7.99 | 7.50 | 6.27 | 7.97 | 7.57 | 8.50 |
| Consumption | -6.37 | -3.91 | -2.93 | -0.44 | -5.60 | -6.47 | -4.71 |
| Investment | -28.96 | -16.55 | -13.98 | -1.82 | -23.80 | 116.95 | -24.76 |
| Nontradable output | -6.37 | -3.75 | -2.78 | -0.54 | -5.23 | -6.65 | -3.25 |
| Tradable output | 3.89 | 2.24 | 1.95 | 0.31 | 5.06 | 8.63 | 4.38 |
| ***Asset and Debt*** | | | | | | | |
| Wealth | -7.74 | -4.66 | -4.08 | — | -7.62 | -7.68 | -7.48 |
| Housing price | -33.33 | -21.76 | -10.31 | — | -33.15 | -32.92 | -32.55 |
| Debt | -17.81 | -10.88 | -9.35 | — | -17.70 | -17.63 | -17.37 |
| ***TFP Related*** | | | | | | | |
| TFP | -1.45 | -0.95 | -0.65 | -0.15 | -1.54 | -2.07 | -0.07 |
| Labor productivity | -1.45 | -0.95 | -0.65 | -0.15 | -1.51 | -1.64 | -0.09 |
| Labor quality | 1.01 | 0.74 | 0.55 | 0.10 | 0.73 | 0.58 | 0.93 |
| Search effort | -5.03 | -3.14 | -2.17 | -0.49 | -4.68 | -4.90 | -4.19 |

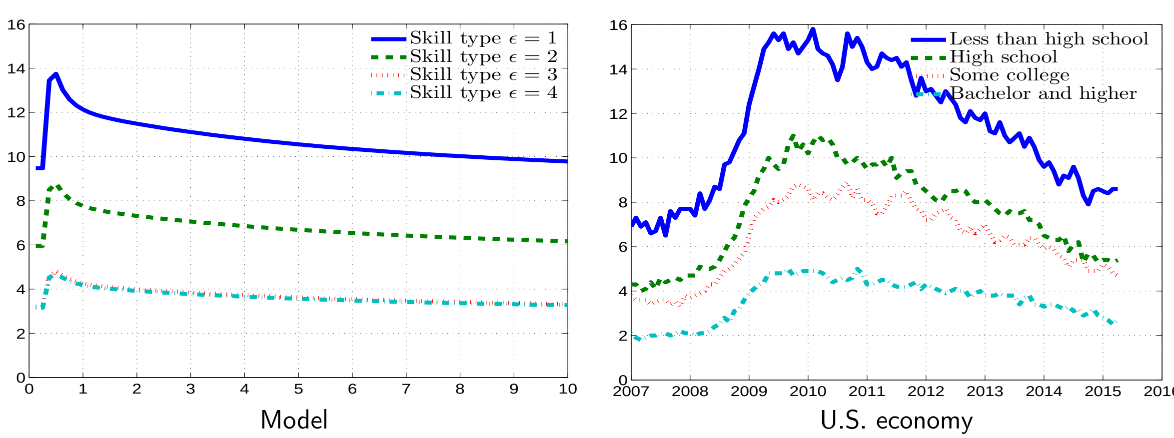
How this all fits together is shown in the first column of Table 7 and in Figure 6. The table shows the values of the largest drop in most variables arising from the main experiment: GDP falls 3.5%, consumption 6.4%, and investment 29%. The fall in GDP is much smaller than that of consumption and investment because of a massive increase in net exports. All of the reduction in investment and tradable consumption becomes exports. Output is reallocated from the nontradable to the tradable sector, but the drop in nontradables is much larger than the increase in tradables because of the adjustment costs. Unemployment increases to almost 9%.

House prices fall by 18%, close to the maximum that occurs without bankrupting some households (we change this requirement in Section 6.1 to explore the effects of a slightly larger financial shock). Firms' values fall little, so the overall fall in wealth is 8%, but because of the portfolio composition across households, poor people lose the most.

Variations in households' search effort lead to variations in measured total factor productivity. When households lower their consumption of nontradables, they lower both the quantity consumed of each variety and the number of varieties they choose by reducing the amount of search effort.[22] In the model, TFP declines by 1.5% even if only the nontradable sector is subject to search frictions.

Our model shares with the data that high-skilled workers face a lower job separation rate. In the recession, the pool of employed contains a higher fraction of skilled workers, and the labor quality increases accordingly, as in the data. The left panel of Figure 5 shows the evolution of the unemployment rate for the various skill groups. The lower the skills, the larger the increase in the unemployment rate. This pattern is what happened in the U.S. economy, as the right panel of the figure shows. The unemployment rate for high school dropouts increased to a level as high as 16%, whereas the unemployment rate for those with a college degree or higher only moves between 2% and 5%. As documented in Fang and Nie (2013) and Lifschitz, Setty, and Yedid-Levi (2015), over the business cycle, workers with different educational attainment share similar job finding rates, but more educated workers have a much lower job separation rate. Our steady-state calibration captures this pattern, which results in heterogeneous unemployment rate dynamics during the transition.

Figure 5: Cross-Sectional Change of Unemployment Rate




In the period when the financial shock occurs, output falls only because of the drop in productivity that results

[22] Appendix B has a discussion of the behavior of shopping effort and shopping time during the Great Recession.

from households' lower effort, since capital and labor are predetermined. After this first period, the reductions in hiring and investing kick in. The tradable sector reallocates lower consumption and investment to exports and starts expanding slowly.

Figure 6 displays the transition paths of the most important aggregate variables in our main experiment. After the financial shock, output falls by 3.5% and then gradually recovers. The recovery of consumption and unemployment is also quite slow—much slower than that of investment. The former is slowed by the requirement that household savings must recover, an endogenously generated process. The recovery of investment is due to the adjustment costs and the need to track the demand for nontradables. The recovery of TFP follows that of consumption.

Housing prices never recover completely, poor households do not find it worthwhile to hold enough assets to consume a lot of housing, and the financial shock limits their access to credit. Furthermore, the shock to the interest rate markup increases the user cost of housing for borrowers. Wealth is also slow to recover because it requires the accumulation of savings after the price losses induced by the shock.

The fall in consumption is not immediate; it takes three periods to achieve its largest size because the considerable installed capacity of nontradables, which only slowly gets reduced, induces a large reduction in the price of nontradables/ This reduced price makes nontradables more attractive relative to tradables for a while. The large fall in the relative price of nontradables (or internal devaluation) does not really have a data counterpart. However, such a counterfactual implication for price dynamics can be eliminated by adding financial frictions on the firm side and posing consumers, as capital as in Gilchrist, Schoenle, Sim, and Zakrajsek (2014), or by allowing firm entry and exit, as explored in our companion paper. We abstract from expanding the model in these directions to improve the match with the data. Our model is quite complicated as it is now.

### 5.2 Decomposition: Only Collateral Constraint or Borrowing Surcharge Changes

What feature of the financial shock matters more: the higher loan to value ratio or the increased markup to loans? To answer, we pose these two parts of the financial shock separately. Figure 7 poses the outcomes of the main experiment with both parts of the financial shock and each one of them separately. Two properties stand out: the effect of the collateral constraint is larger (60 to 40), but it also recovers faster as households accumulate more wealth. In fact, the interest rate markup has larger long-run effects.

### 5.3 The Reduction in Housing Prices

How important is the amplification mechanism of the reduction in housing prices? It is absolutely critical. To assess its importance, we consider the effects of the financial shocks without affecting housing prices. This can be seen as

Figure 6: Aggregate Economy Response in the Baseline Model

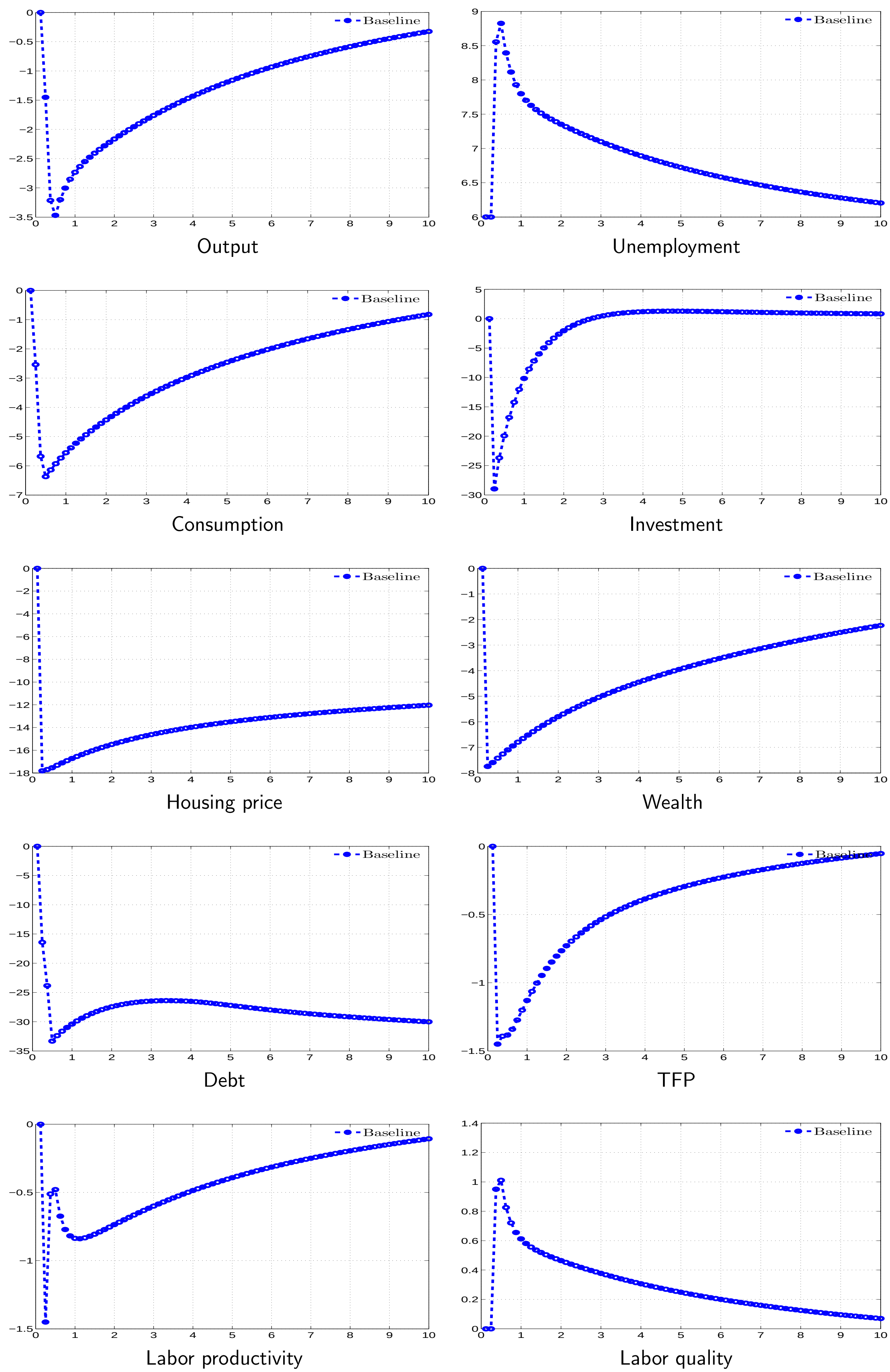
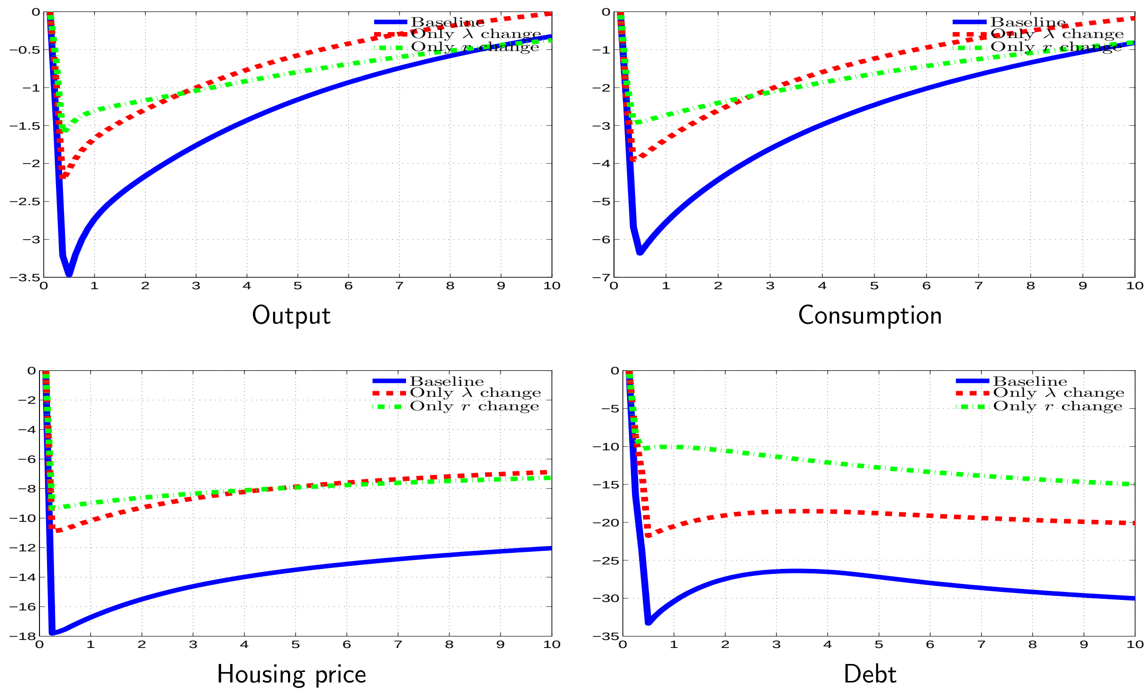


Figure 7: Aggregate Economy Response: Collateral Constraint Shock and Borrowing Surcharge Shock



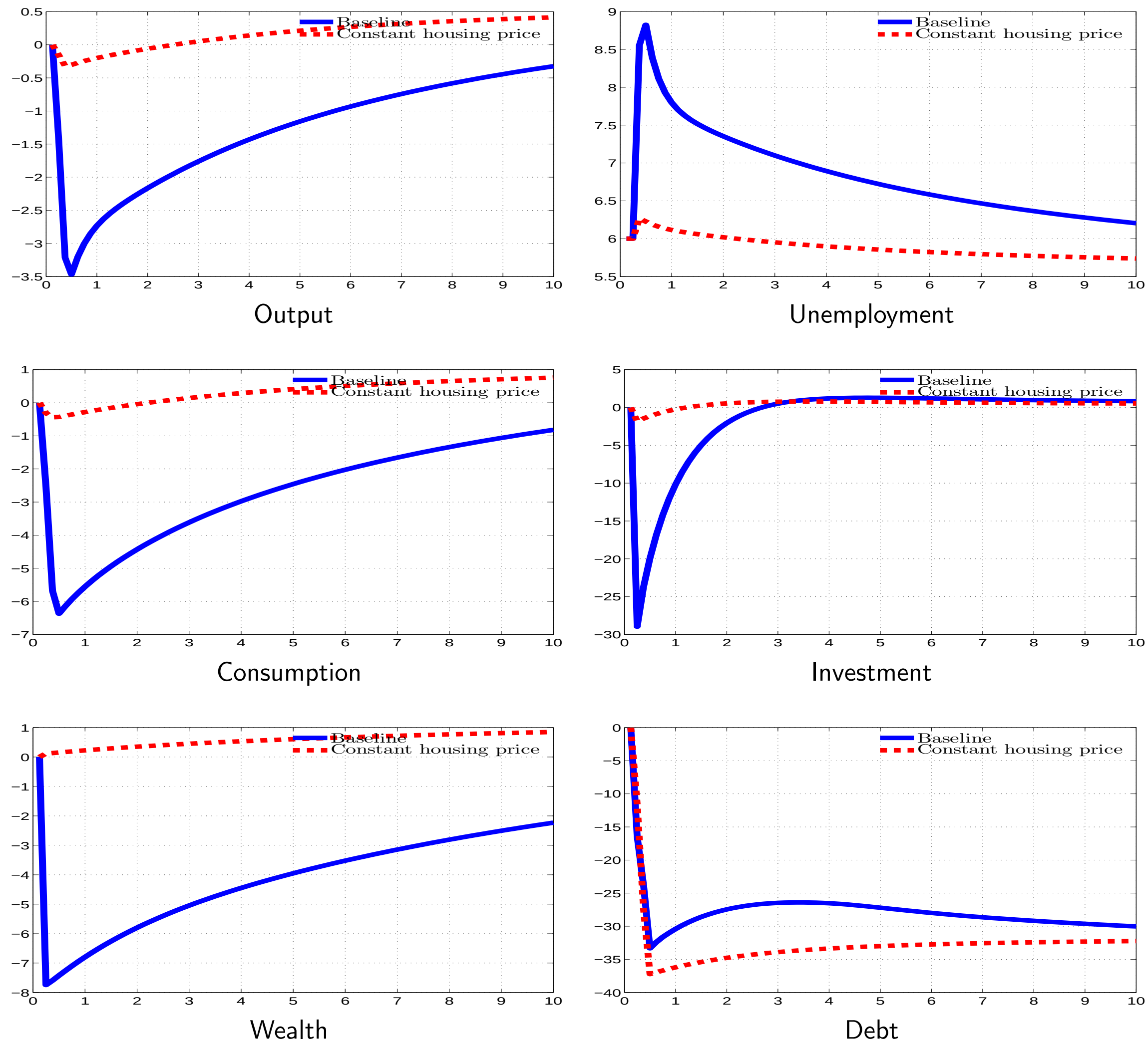

either a disequilibrium exercise to isolate the role of housing price in generating the recession, or the effects of the financial constraint in an economy where housing services are yielded by a storable good that can be transformed into the tradable good at rate $r$ in one direction and at rate $r + \varsigma$ in the other. Consequently, its price is fixed and its quantity can move around. Specifically, we fix the price of houses to equal its value in the initial steady state, and we keep it there throughout the transition, letting the quantity adjust.

Figure 8 compares the responses to the shock under the main experiment and under constant housing prices. The recession essentially disappears with constant housing prices: output falls by less than 0.5% on impact and starts to grow slowly after that, converging to more than 1 percent of higher output in the long run. Households immediately adjust to the more stringent borrowing conditions by reducing their housing holdings and they increase their savings to adapt to the new circumstances.

The difference between the two economies is the size of the wealth effect. Under constant prices, there is almost a zero wealth effect: what nontradable firms lose is compensated by the gains of tradable firms, both minute in any case. Households that are directly affected by the tighter borrowing constraint simply reduce their housing holdings, and save more in financial assets. This comparison highlights the central role of the housing bust in generating a recession. It has dual effects that reinforce each other: the worsening households' balance sheet condition and the further tightening of households' collateral constraint.

This exercise is also helpful in seeing why in economies with ad hoc borrowing constraints à la Aiyagari (1994),

Figure 8: Aggregate Economy Response: Constant Housing Prices

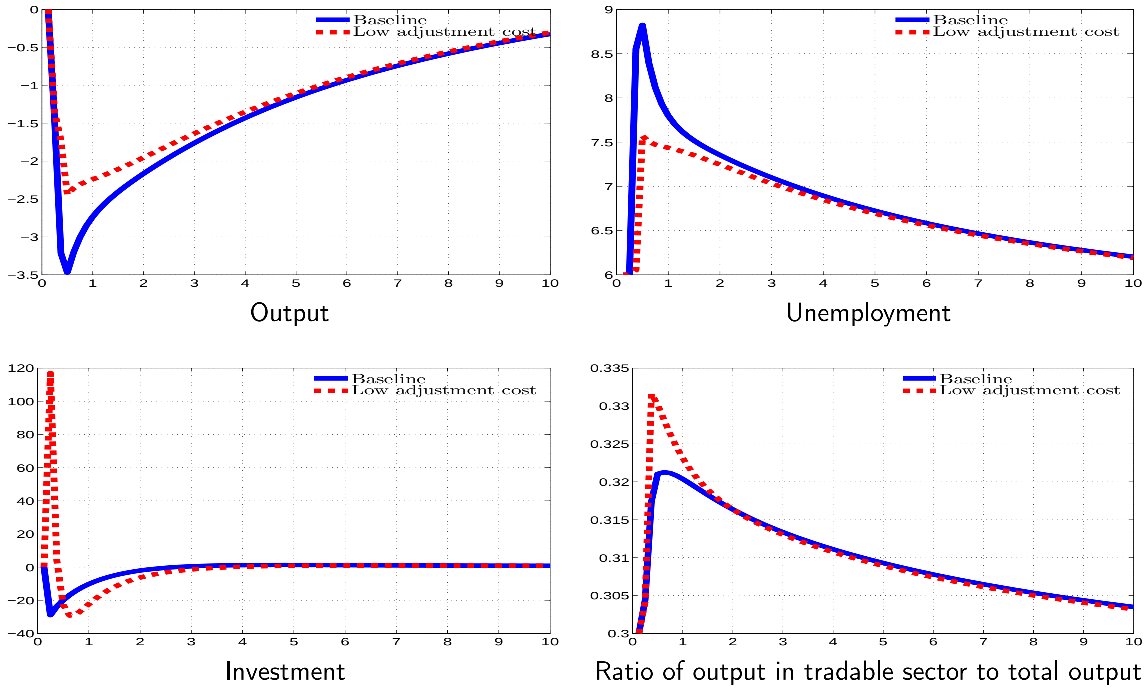



its tightening has only limited effects on economy activity (see Guerrieri and Lorenzoni (2011), Huo and Rios-Rull (2015), and Phillips and Herkenhoff (2015), for example). Changes in the ad hoc borrowing constraint affect only the very poor households directly (that is, the 10% to 15% with negative net worth), and these households make a very small contribution to overall economic activity. Richer households are affected and increase their savings for precautionary reasons, but they do so very slowly. Housing, not only exerts a direct negative effect on wealth, but also greatly affects the large number of households with some mortgage debt (70%).

### 5.4 Role of Adjustment Costs and Decreasing Returns to Scale

In our model economy, the recession requires difficulties in reallocating production from nontradables to tradables. This occurs via both adjustment costs and decreasing returns to scale. To see what role each channel plays, we explore an economy with the same decreasing returns to scale as the baseline but with no adjustment costs. Its

Figure 9: Aggregate Economy Response: No Adjustment Costs in the Tradable Sector




properties are featured in Figure 9.

We see that output falls by 2.5% and unemployment goes up to 7.5%—not as much as in the main experiment but still a sizeable recession. Investment, however, more than doubles as resources are immediately reallocated to the tradable sector. The expansion of output in the tradable sector is much larger and faster than in the baseline. The combination of decreasing returns to scale and the recovery of wages makes the tradable sector go back down after the initial expansion. Clearly, decreasing returns to scale also play an important role, as otherwise, there would be no increase in unemployment because workers would have been reallocated almost immediately to the tradable sector.

As Alessandria, Pratap, and Yue (2013) document, expansions of the exporting sector tend to be slow, which indicates that severe adjustment costs in the tradable sector are required to impede a huge expansion of this sector when the recession occurs. If anything, our calibration assumptions underestimate the role of these adjustment costs by allowing a fast expansion of exports and of net exports.

### 5.5 Role of Endogenous Productivity

One of the ingredients in our economy, and a theoretical contribution on its own, is that a negative wealth effect diminishes productivity endogenously. Unlike in Bai, Ríos-Rull, and Storesletten (2011), Petrosky-Nadeau and Wasmer (2015), or Huo and Rios-Rull (2015), in our economy households reduce their consumption partly by reducing consumption per variety and partly by reducing the number of varieties, which implies a reduction in their search effort.[23] We implement the features of no endogenous productivity feature by dramatically reducing parameter $\mu$ from a value of 0.8 to a value of 0.05. Recall that $\mu$ is the exponent of search effort in the matching function. When it gets close to zero, there are still search frictions, but measured TFP will effectively be independent of household search effort.

Figure 10: Aggregate Economy Response: Role of Goods Market Matching Elasticity

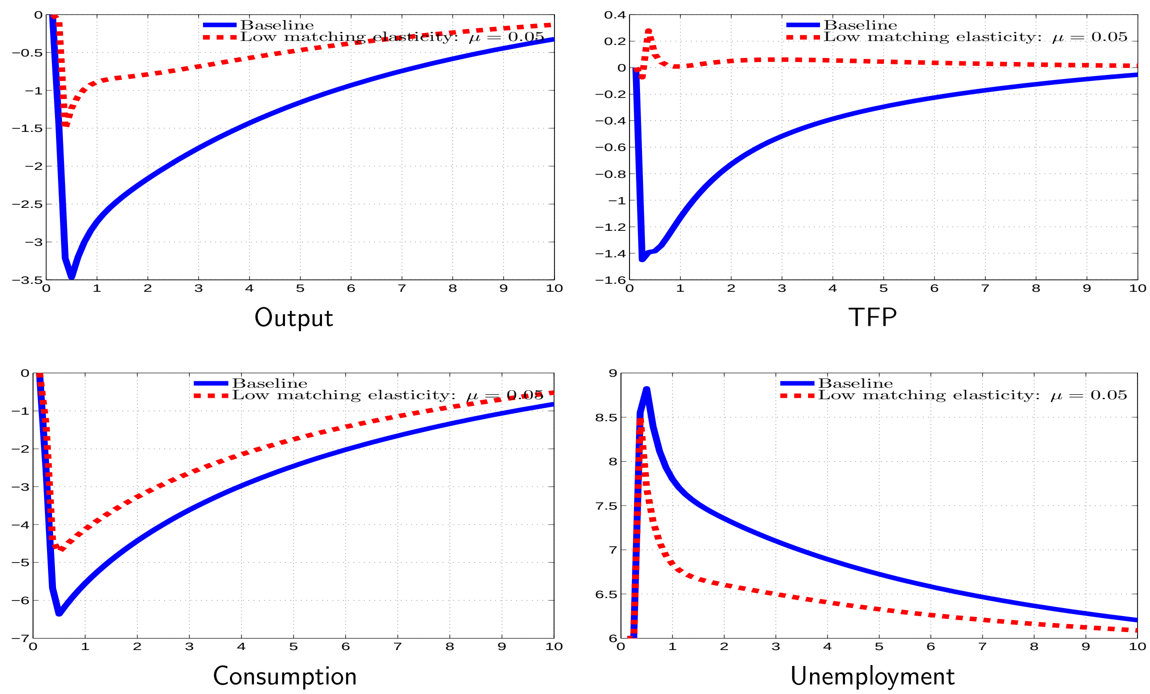



Figure 10 shows what happens. The drop in output is much smaller because all of the decline in output is due to the drop in employment and not in productivity (however, there is a tiny increase in measured TFP due to the increase in labor quality that is associated with higher unemployment). Unemployment goes up by 15% less than the baseline, and its recovery is faster. As a result, consumption falls by 4.5% rather than by the 6.5% that we obtained in the main experiment.

### 5.6 Role of Wage Rigidity

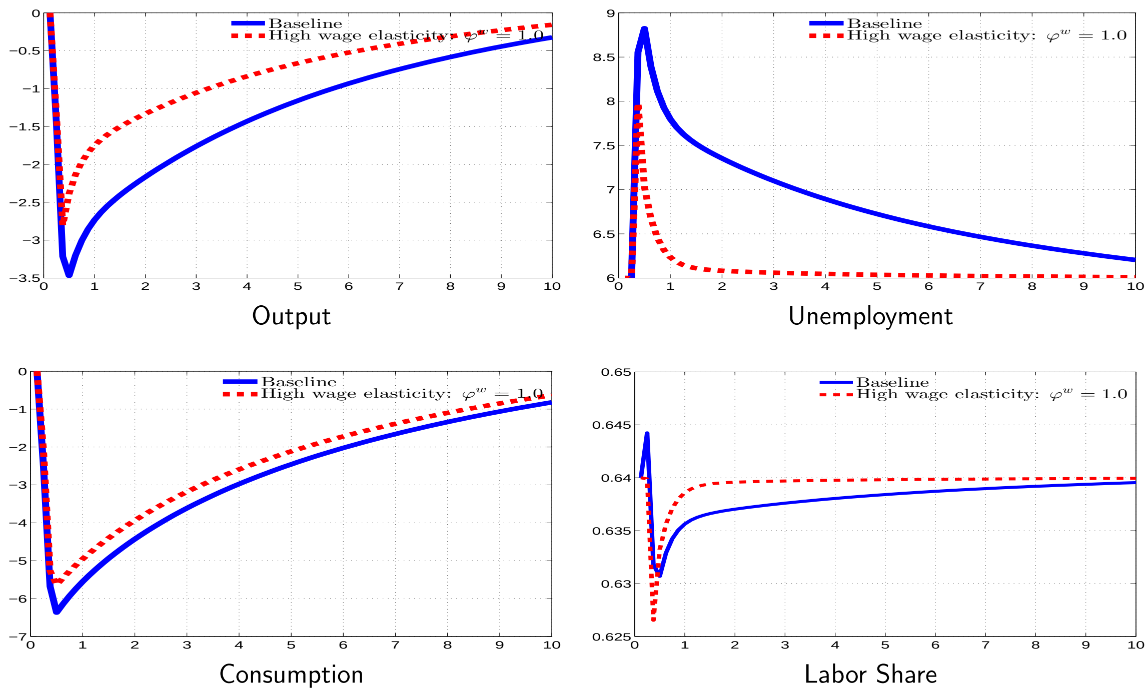
The degree of wage rigidity in the economy is determined by the wage elasticity parameter $\varphi^w$ in equation (61). Households are always willing to work, so the lower the salary, the higher is output. To see the extent to which this matters, we pose an economy where the elasticity of wages is unitary.[24] As we can see in Figure 11, labor

[23] Again, a competitive search version of this economy will pose a partition of locations by both prices and market tightness, with rich agents paying more but searching less. This would be consistent with the cross-sectional evidence posted by Aguiar, Hurst, and Karabarbounis (2013) and Kaplan and Menzio (2013) of the higher search effort for specific goods by certain low income groups, e.g., the unemployed, the retired.

[24] To see what this implies, consider that the wage equation that we are using is in logs $\widehat{w} = \varphi^w\, \widehat{y}$ and that in the short run, output is determined by labor, yielding $\widehat{y} = z + \alpha\, \widehat{n}$, where $\alpha$ is the contribution of labor in the production function, and $z$ is the Solow residual. It follows that the labor share is given by $\widehat{\tau} = (\widehat{w} + \widehat{n}) - \widehat{y} = \widehat{n} - (1 - \varphi^w)\widehat{y} = \widehat{n} - (1 - \varphi^w)(z + \alpha\widehat{n}) = [1 - (1 - \varphi^w)\alpha]\widehat{n} - (1 - \varphi^w)z$. Whether the labor share increases or decreases in the recession depends on the relative change in $n$ and $z$. In our model, employment

share in the main experiment stays below the long-run level for a long time (except for the very beginning), whereas labor share with a unitary elasticity drops instantaneously but recovers much faster. The lackluster behavior of labor share, as documented by Karabarbounis and Neiman (2014), seems to be more consistent with the baseline than with the unitary elasticity of substitution. The unemployment rate increases to 8% with unitary elasticity,

Figure 11: Aggregate Economy Response: Role of Wage Rigidity

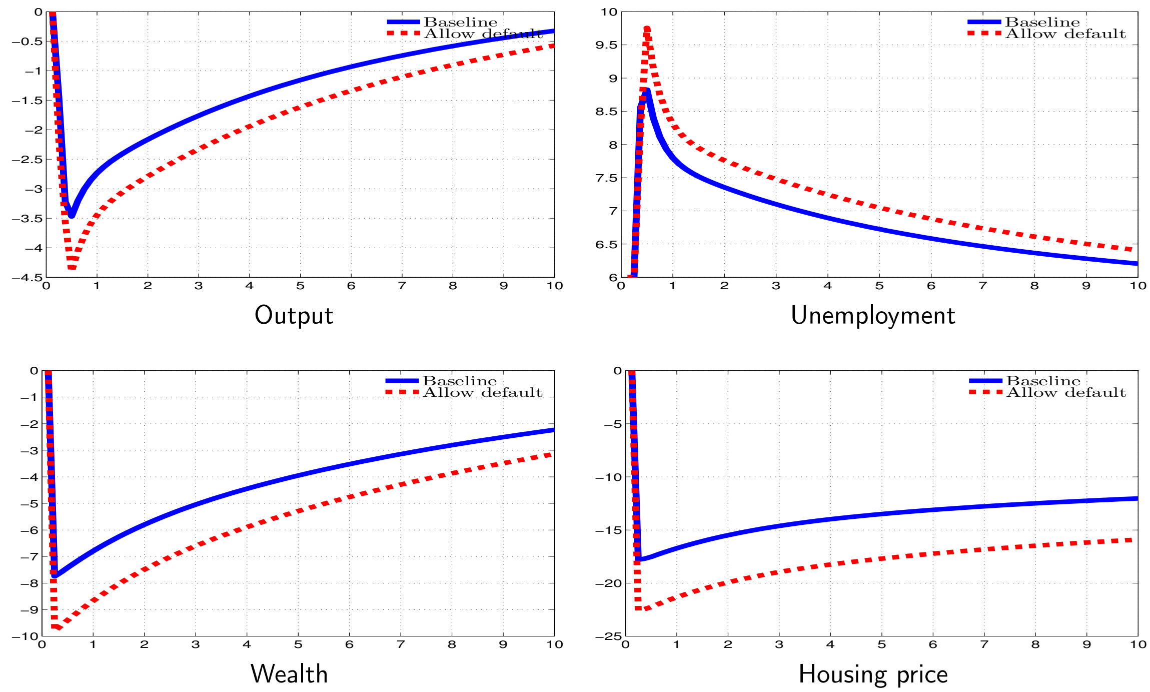



which is lower than that in the main experiment. Most important, the level of the unemployment rate returns to its steady-state value within a year, a fairly fast recovery. In contrast, in the baseline model with more rigid wages, the unemployment rate declines slowly, and the prolonged high unemployment era resembles the slow recovery in the U.S. economy.

## 6 Various Extensions

We now explore various two extensions, that the financial shock may have induced *unexpected* default, and that the home ownership rate is lower than 1.

Figure 12: Aggregate Economy Response: Allowing Default




### 6.1 Allowing Default

During the Great Recession, the foreclosure rate rose sharply (see Calomiris, Longhofer, and Miles (2008), Mian, Sufi, and Trebbi (2011), and Chatterjee and Eyigungor (2015), who document that the cumulative foreclosure rate was between 16% and 20% between 2007 and 2009). Yet, the main experiments in our economy have no foreclosures. We constrained the size of the financial shocks and the baseline value of the collateral constraint to ensure that no household would be left with an empty budget set.[25] We did so because we did not want to consider unexpected losses for lenders without any margin for interest rates to cover possible foreclosures. In this section, we abandon this concern and consider the possibility that housing prices drop beyond the value that all households to maintain positive wealth. In doing this, we impute the unpaid mortgages (the amount of negative wealth held by mortgage holders after the drop in housing prices) as a reduction in the value of the mutual funds that hold the assets of those with positive financial assets. The experiment that we consider has the same collateral constraint as our main experiment but doubles the markup on the interest of loans to 1%. The results are shown in Figure 12. Housing prices fall by more than 20%, generating bankruptcies. The larger wealth loss moves consumption down further and with it unemployment, which jumps to almost 10%, and output, which falls 4.6%.

Clearly, allowing for foreclosures, even in our relatively clumsy way, further amplifies the size of the recession.

initially does not change because of search frictions. All of the movement in output is due to the change in the Solow residual. As a result, the labor share increases initially in the recession. As time goes on, employment becomes the dominating force, and the labor share decreases.

[25] Given the low value of income when unemployed, this means essentially zero wealth.

## 6.2 Some Households with Zero Housing

The homeownership rate in the United States is about two-thirds, whereas in our baseline model, all households have a positive amount of housing (a joint implication of Inada conditions on preferences and the perfect divisibility of housing). This assumption may exaggerate the effects of the financial shock because households with zero housing are not directly affected by the tightening of the collateral constraint and the drop in housing prices (in fact, they may benefit from the latter), even though they still have an incentive to increase their saving for precautionary reasons. In this section, we modify the housing utility function to allow for the possibility of zero housing holding and to explore its quantitative implications.

To pose households with zero housing, we make a small change in the utility function, adding one new parameter, $\underline{h}$. Accordingly, we have

$$v(h) = \begin{cases} \xi_h \log(h + \underline{h}), & \text{if } h < \widehat{h}_1, \\ \frac{\xi_h}{1-\sigma_h}\left(h + \xi_h^1\right)^{1-\sigma_h} + \xi_h^2, & \text{if } \widehat{h}_1 \leq h \leq \widehat{h}_2, \\ \xi_h^3\sqrt{\overline{h}^2 - (\overline{h} - h)^2} + \xi_h^4, & \text{if } h > \widehat{h}_2. \end{cases} \tag{62}$$

When $\underline{h} > 0$, households with relatively low wealth choose positive consumption but zero housing. We recalibrate the economy to match the same steady-state targets as in the baseline model (see Appendix D for details), and we choose $\underline{h}$ such that 32% of households have zero housing.

Figure 13: Policy Function for Housing and Financial Assets in the Zero Housing Economy

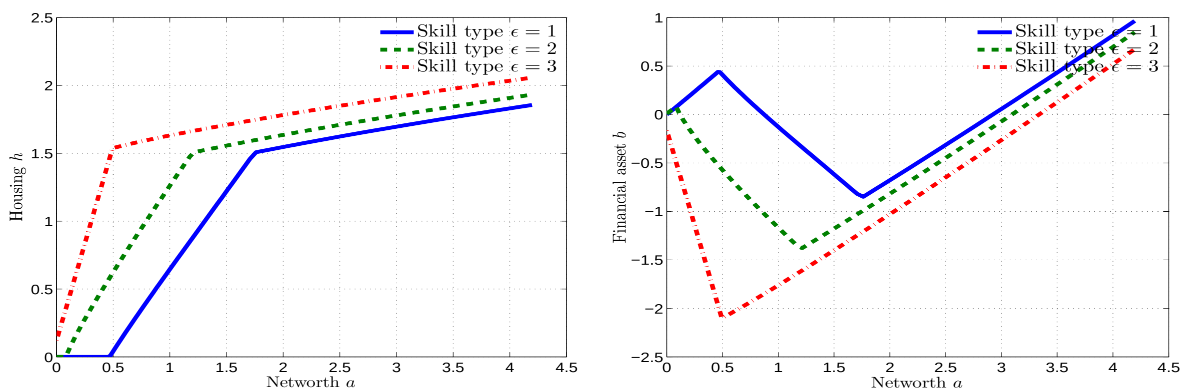
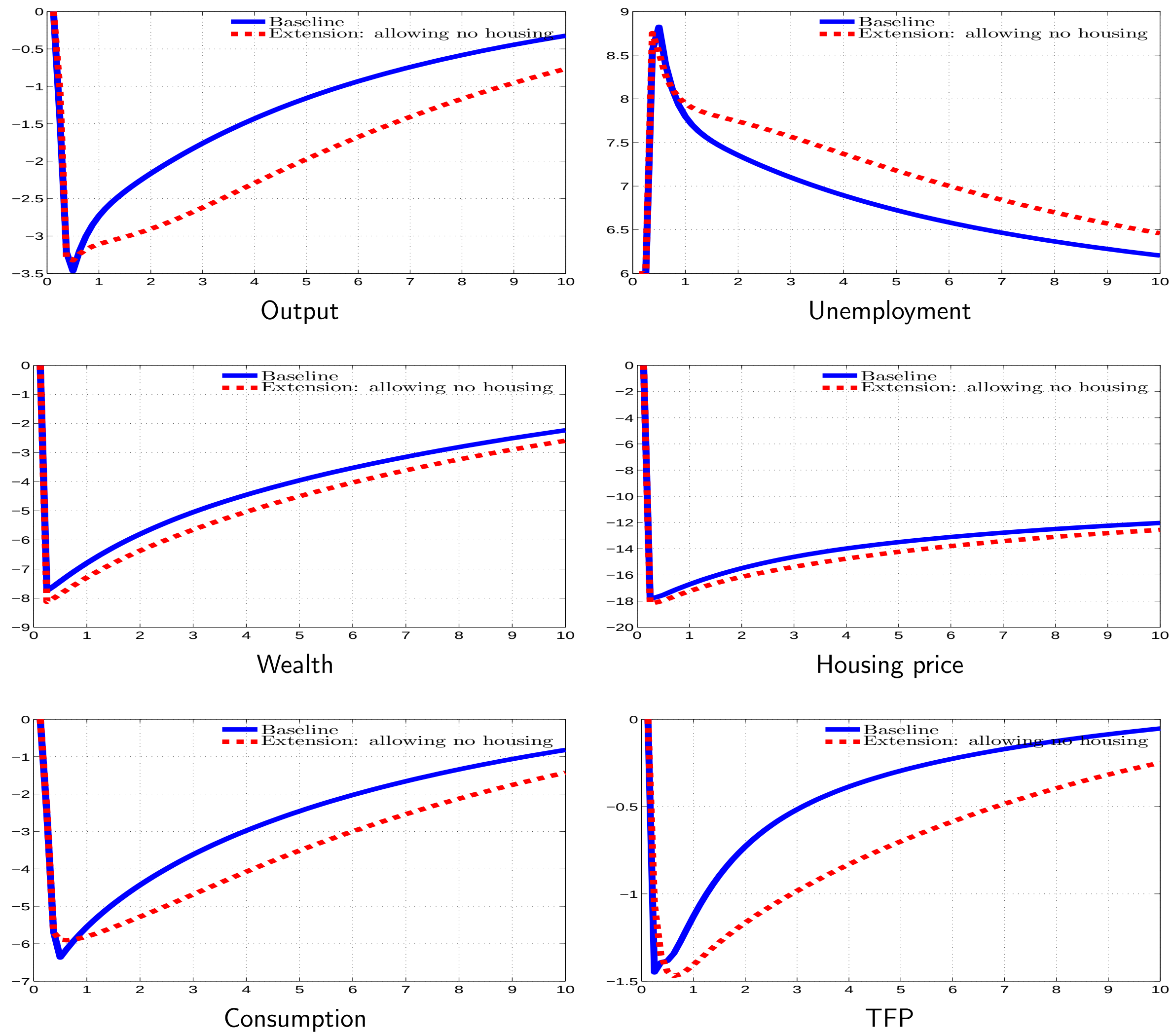



Figure 13 displays the policy functions for employed workers with skill types 1 to 3 in the zero assets economy. In addition to the three groups of the baseline economy that we saw in Figure 4, there is another, poorer, group that does not own any housing (this wealth-type exists only for skill types 1 and 2) and therefore will not suffer any capital loss as a result of the financial shock.

In this recalibrated economy, the same size shock that we used in the baseline economy generates a lower response of housing prices and, consequently, of output. We think, however, that the right comparison is to choose a size

Figure 14: Aggregate Response: Economy with 32% of Households Holding Zero Houses.




Note: The shock to borrowing markup $\varsigma$ to and the goods market elasticity $\mu$ are adjusted to match the fall in housing price and in TFP.

of the shock (the shock to the markup $\varsigma$) and a size of the elasticity of the matching function that replicates the reduction in both housing wealth and measured TFP that we obtained in the main experiment and compare its effects on output, unemployment, and consumption. The results are displayed in Figure 14.

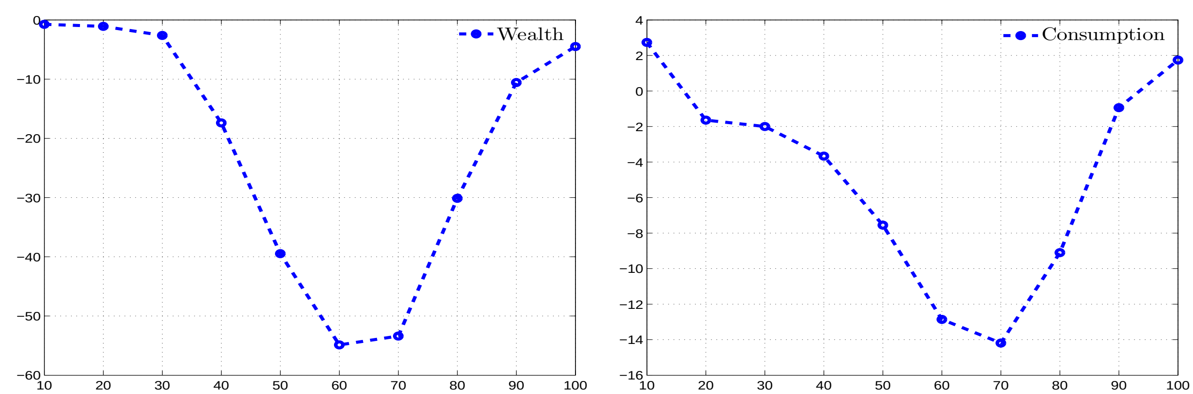
Clearly, once we resize the shocks to replicate the same housing price and TFP falls, the effects on consumption are essentially the same as in the main experiment (actually they are about 8% smaller). The effects are also longer because of the slower response of type 1 households. As we will see below, when we discuss the cross-sectional implications of the Great Recession, the larger shock required to get the same house price drop in the economy with zero housing households makes households in skill group 1 desire to save more, which depresses their consumption much longer (see Figure 16 and Figure 19 in Appendix C).

## 7 Cross-Sectional Implications of the Great Recession

The model has very strong implications about whose consumption dropped the most: those with the largest wealth losses. We explore this issue within the extended model where many households are not homeowners, because in this model, the predictions are sharper and can more readily be compared with the data. One type of evidence is produced by Mian and Sufi (2010, 2011, 2014), who show that larger housing price drops lead to more severe recessions and larger consumption drops across U.S. metropolitan areas. Also, the response of consumption to housing price changes is particularly large for highly leveraged and underwater households.[26]

Petev, Pistaferri, and Eksten (2011) and Parker and Vissing-Jorgensen (2009) provide more direct evidence of which households cut consumption the most based on the Consumer Expenditure Survey. Petev, Pistaferri, and Eksten (2011) find that the annual consumption growth rates between 2007 and 2009 by the income quantiles are -3%, -2%, -3%, -4%, -5%, with the middle and rich households dropping the most. Conditional on initial net worth, the consumption growth rate of the bottom 50% is -2%, is -7% for the top 10%, and is -3% for the rest. Parker and Vissing-Jorgensen (2009) find that high-consumption households are significantly more exposed to aggregate fluctuations than low-consumption households. Between 2008 and 2009, the ratio of consumption of the top 20 to the bottom 80 falls by 9%. They explain this fact by showing that the income of high-income households is more exposed to aggregate fluctuations.

Figure 15: Change of Wealth and Consumption by Initial Wealth Condition

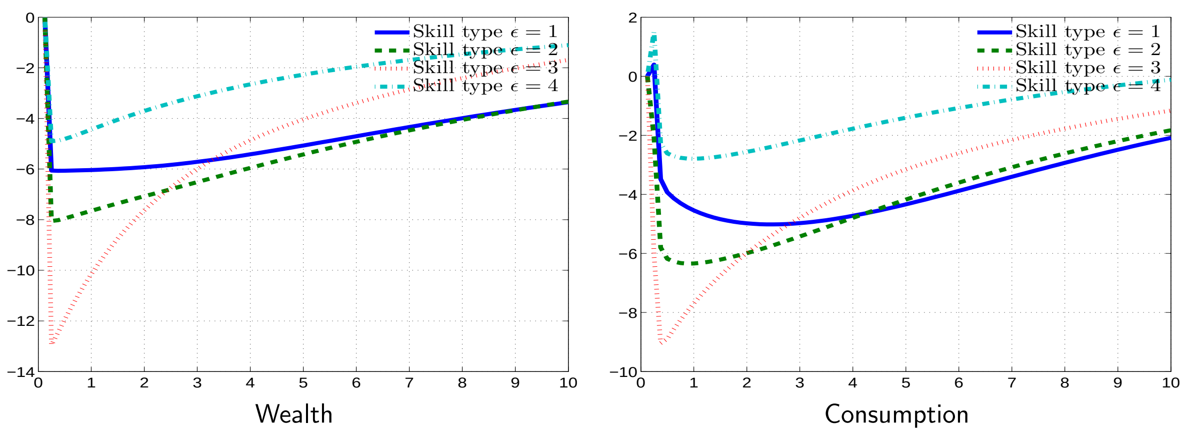



We can explore which households bore the brunt of the fall in consumption in our model. Figure 15 shows the reduction in wealth and consumption for different households sorted in deciles by wealth. The wealth of the poorest households barely changes because most of these households have zero housing. The richest households also have a relatively small change of wealth because housing is a small fraction of their total wealth. The households in the middle suffer the most, since the majority of their wealth is housing equity. The change of consumption mimics the

[26]In a model related to ours, Kaplan, Mitman, and Violante (2015) explore how more inelastic house construction areas lead to more severe recessions.

change of wealth.[27] Figure 16 shows average wealth and consumption paths after the financial shock for each of the four skill groups. Households of skill types 2 and 3, are the ones with the largest loss of wealth (they are highly leveraged), and consequently, they cut their consumption the most. This is the case even though it is the low-skilled workers (group 1) that suffered the most in terms of unemployment. All these cross-sectional facts are consistent with the evidence posted by Parker and Vissing-Jorgensen (2009) and Petev, Pistaferri, and Eksten (2011).

Figure 16: Change of Asset and Consumption for Different Skill Types: Zero Housing Economy



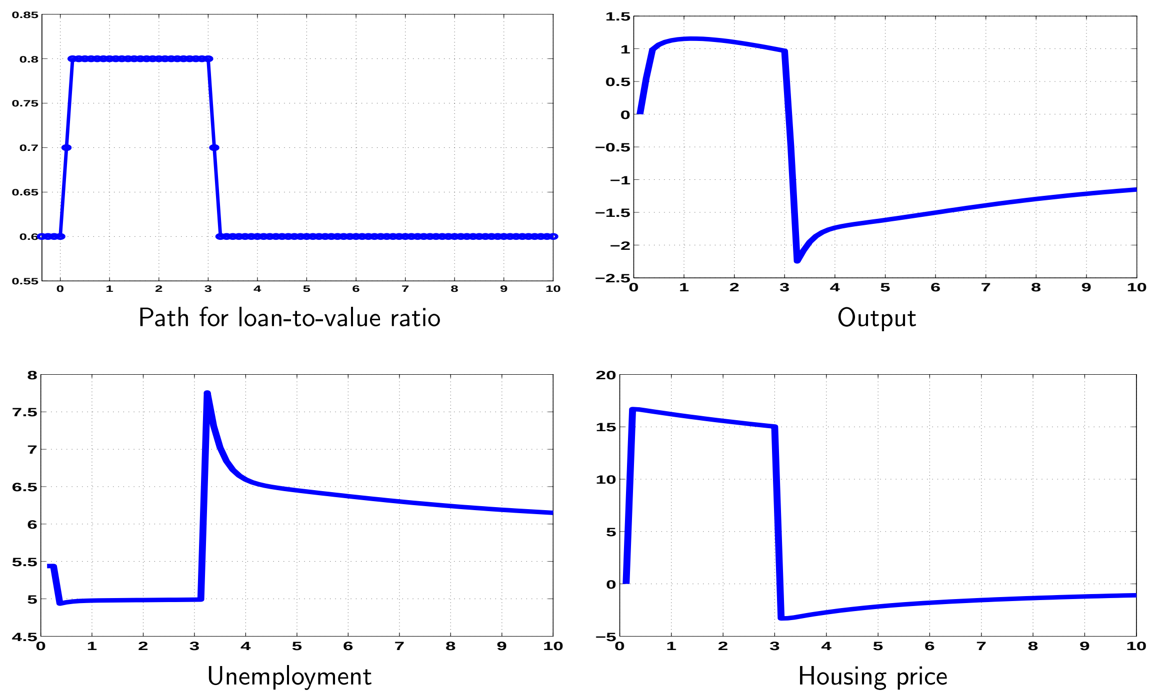

## 8 Credit Cycles: Expansion and Recession

We finish the paper with an exploration of the possible role of credit expansion in the boom years previous to the Great Recession. To this extent, we pose two financial (MIT) shocks—one that expands the ability to borrow and one that contracts it. We pose as an initial condition the low loan-to-value ratio and the high markup (the situation after the shock in the main experiment). We then expand credit by surprise (to the initial condition of the baseline economy and with households believing that these conditions will hold forever). After three years, we surprise households again, with the credit terms returning to the original terms. We refer to this cycle as the boom and bust cycle.

Figure 17 displays the implied path of the loan-to-value ratio and various aggregate variables in the boom and bust cycle. We see that in the boom stage, output and employment both increase. Because of the lower down payment ratio, households can now borrow more than before and bid for houses, inducing a large price increase. As a result, total debt grows. The positive wealth effect is what increases consumption, expanding the nontradable sector. When the financial bonanza is over, households cut their debt and expenditures, resulting in a process similar to that in our main experiment.

[27] Actually, there is a brief spike in consumption for the poorest and richest households due to a large initial drop in the price of nontradables. During the transition, consumption in tradable goods drops by 9%, and consumption in nontradable goods drops by 5%. Although this negative spike in the price of nontradables did not occur in the United States, it can be averted by a slight modification in the timing of the price posting of nontradable firms: that is, the price is posted before the realization of the financial shock. This

Figure 17: Aggregate Economy Response: Boom and Bust Cycle




Crucially, the boom and the bust are not symmetric. With credit expansion, the boom is relatively mild, whereas the recession followed by the credit tightening is much more severe because when the loan-to-value ratio increases, it relaxes households' collateral constraint and allows households to attempt to increase their housing, which raises prices. The boom in wealth induces an increase in consumption, but households want to spread this higher consumption over a long time, thus inducing a small jump in consumption. In contrast, a tightening of the loan-to-value ratio prompts many households to consume less housing than they would like, and they respond with a sharper increase in saving. The intuition is similar to that explained in Guerrieri and Iacoviello (2013).

## 9 Conclusion

We have presented a theory of the Great Recession based on the negative wealth effects induced by an adverse shock to the ability of households to acquire loans amplified via a large reduction in house prices. We have done so in the context of a quantitatively sound model that replicates the main features of the U.S. economy in terms of both the main aggregates and the distribution of income and wealth.

We have shown the ingredients necessary for a large recession to occur: the concentration of income and wealth, the leverage of households, the real frictions that make it difficult to quickly transform an economy from being consumption oriented to being saving or export oriented, and the contribution of consumption expenditures to productivity.

will result in a further drop in output at the time of the financial shock.

Research taken in three obvious directions will improve our understanding of the Great Recession:

1. Our modeling of the housing market has been quite pedestrian, with no adjustment costs of either housing or the amount borrowed, despite a growing amount of evidence that these costs are large (see Kaplan and L. Violante (2014)). Our modeling choices require households to adjust their housing every period to continually satisfy their collateral constraint. The shock that we pose to the loan-to-value ratio may be misplaced. It is possible that the increased difficulties in borrowing may have been in terms of the payment-to-income ratio. All of this suggests that a richer model of the housing and mortgaging decisions may be important.

2. In our economy, the fall in investment is automatically exported, without any loss of profits or employment, whereas in the data, exports always take time to expand and the investment-producing sectors also suffered during the Great Recession. To deal with this issue, we should differentiate more sectors of production so that the fall in investment contributes to the reduction in output. This is particularly the case if we think of the construction of both business structures and houses, which are sectors with features of nontradables rather than tradables.

3. Finally, and perhaps most important, we have posed a financial shock as a primitive, when clearly that should not be the case. A better understanding of the determinants of household credit is required.

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## Appendix

# A Details on the Construction of the Data

## A.1 Data Source

1. Output: Real Gross Domestic Product. Source: U.S. Bureau of Economic Analysis.
2. Investment: Gross Private Domestic Investment. Source: U.S. Bureau of Economic Analysis.
3. Consumption: Personal Consumption Expenditures. Source: U.S. Bureau of Economic Analysis.
4. Net worth: Net Worth, Households and Nonprofit Organizations. Source: Board of Governors of the Federal Reserve System, Balance Sheet of Households and Nonprofit Organizations.
5. Mortgage Debt: Home mortgages, Households and Nonprofit Organizations. Source: Board of Governors of the Federal Reserve System, Balance Sheet of Households and Nonprofit Organizations.
6. Housing value: Real estate (households), Households and Nonprofit Organizations. Source: Board of Governors of the Federal Reserve System, Balance Sheet of Households and Nonprofit Organizations.
7. Unemployment: Civilian Unemployment Rate. Source: U.S. Bureau of Labor Statistics.
8. Labor share: Labor Share, Nonfarm Business Sector. Source: U.S. Bureau of Labor Statistics.
9. Per capita output: Real Output Per Person, Nonfarm Business Sector. Source: U.S. Bureau of Labor Statistics.
10. Unemployment by education: Unemployment Rates by Educational Attainment. Source: U.S. Bureau of Labor Statistics.
11. TFP measured by total hours: TFP. Source: http://www.frbsf.org/economic-research/indicators-data/total-factor-productivity-tfp
12. Labor quality: Labor composition. Source: http://www.frbsf.org/economic-research/indicators-data/total-factor-productivity-tfp

## A.2 Data Construction

**Real Wage:** The real wage is constructed in the following way:

$$\text{Real wage} = \frac{\text{Per capita output}}{\text{Labor share}} \tag{63}$$

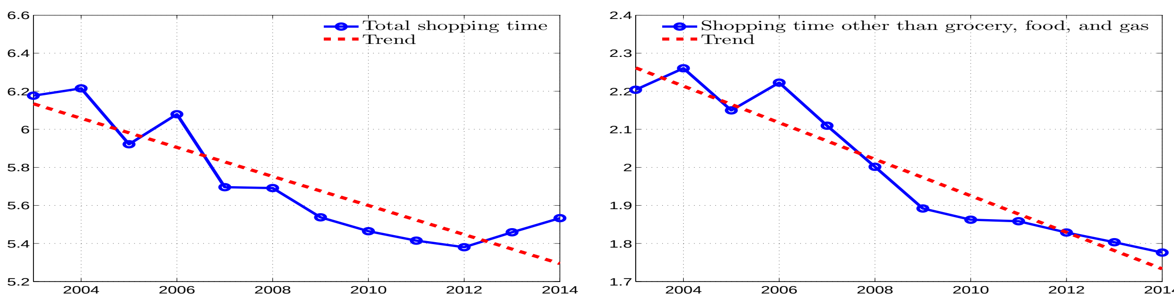
**TFP measured by total labor inputs** TFP measured by total labor inputs is constructed in the following way:

$$\log(\text{TFP measured by total labor inputs}) = \log(\text{TFP measured by total hours}) - (1 - \text{Labor share})\log(\text{Labor quality}) \tag{64}$$

# B A Discussion of Shopping Effort and Shopping Time

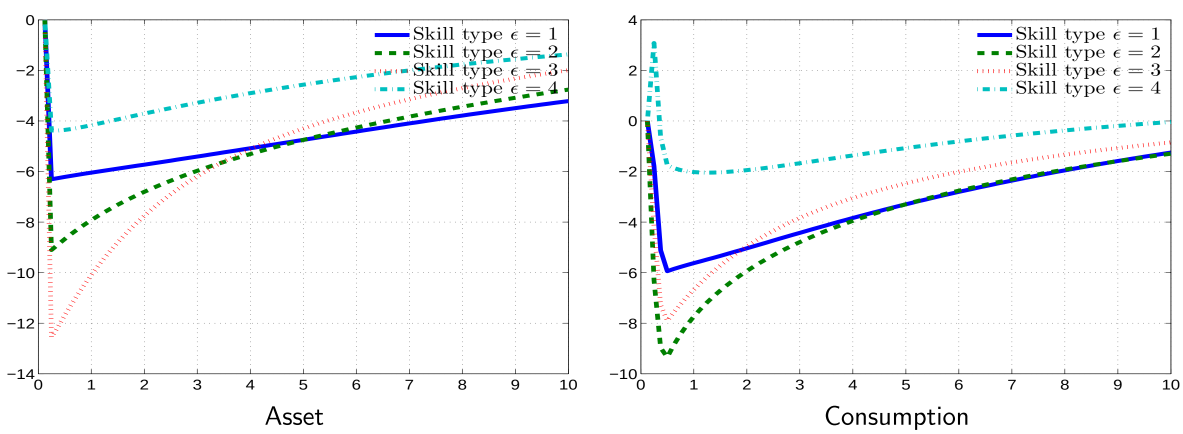
We interpret search effort as the disutility associated with acquiring consumption, such as waiting for a restaurant table or booking hotels online, waiting for a haircut, commuting to the dentist, settling for a less preferred color in a new car, and so on. Consequently, the search effort is different from just the shopping time spent on finding a cheaper price, such as searching for coupons or sales in a grocery store, which is the notion used by Aguiar and Hurst (2005) and Aguiar and Hurst (2007). Whether consumers actually show up in restaurants or theatres affects the occupation rate of the economy, and in recessions, firms operate with a lower capacity. As shown in Aguiar and Hurst (2005), retired and unemployed people eat at restaurants less frequently than working people. Even though shopping time is a much narrower notion than our interpretation of search effort, we find that total shopping time and the time spent shopping for goods other than necessities tend to be procyclical, as shown in Figure 18. However, we do not want to insist on the cyclicality of shopping time, because the survey data are still relatively short and there is a trend of the time spent on shopping. For example, based on cross-sectional evidence, Aguiar, Hurst, and Karabarbounis (2013) find that shopping time increased during the Great Recession, whereas Petrosky-Nadeau, Wasmer, and Zeng (2014) find that shopping time is procyclical.

Figure 18: Shopping Time




# C Additional Graphs of Interest

Figure 19: Change of Asset and Consumption for Different Skill Types: Baseline Economy



# D Additional Tables

**Parameters of the Model in Section 6.2** In this exercise, we choose the same shock to the loan-to-value ratio $\lambda$ and choose the shock to $\varsigma$ such that the model generates the same drop in housing price as in the baseline model. The required increase in the interest rate markup is 80 basis points annually. Tables 8, 9, and 10 present the recalibrated parameters in this model.

Table 8: Endogenously Determined Parameters in the Zero Housing Economy: Aggregate

| Target | Data | Model | Parameter | Value |
|---|---|---|---|---|
| ***Aggregate Targets*** | | | | |
| Share of tradables | 0.30 | 0.30 | $\omega$ | 0.97 |
| Occupancy rate | 0.81 | 0.30 | $\nu$ | 0.81 |
| Capital-to-output ratio | 2.00 | 2.00 | $\delta_k$ | 0.01 |
| Labor share in nontradables | 0.64 | 0.64 | $\alpha_0$ | 0.27 |
| Symmetry of labor coeff. in nontradables | $\alpha_1 = \alpha_2$ | | $\alpha_1$ | 0.36 |
| Labor share in tradables | 0.64 | 0.64 | $\theta_1$ | 0.66 |
| Vacancy-cost-to-output ratio | 0.02 | 0.02 | $\kappa$ | 0.42 |
| Home-production-to-lowest-earning ratio | 0.50 | 0.50 | $\overline{w}$ | 0.07 |
| Wealth-to-output ratio | 4.00 | 4.01 | $\beta$ | 0.98 |
| Housing-value-to-output ratio | 1.70 | 1.70 | $\xi_h$ | 0.54 |
| Unemployment rate | 6.00 | 6.00 | w | 0.68 |
| ***Cross-Sectional Targets*** | | | | |
| Fraction of housing held by bottom 70% | 0.25 | 0.25 | $\widehat{h}_1$ | 1.48 |
| Fraction of housing held by bottom 80% | 0.39 | 0.39 | $\widehat{h}_2$ | 4.14 |
| Fraction of housing held by bottom 90% | 0.58 | 0.58 | $\sigma_h$ | 3.79 |
| Fraction of households with no house | 0.32 | 0.32 | $\underline{h}$ | 0.81 |
| ***Units Targets*** | | | | |
| Output | 1.00 | 1.00 | $z_N$ | 0.93 |
| Relative price of nontradables | 1.00 | 1.00 | $z_T$ | 0.51 |
| Market tightness in goods markets | 1.00 | 1.00 | $\xi_d$ | 0.04 |

Table 9: Parameters Related to the Endowment Process in the Zero Housing Economy

| Parameter | Value | Target | Value | Model |
|---|---|---|---|---|
| $\delta_n^1$ | 0.083 | Job duration for type 1 | 1.5 year s | 1.5 years |
| $\delta_n^3$ | 0.025 | Job duration for type 3 | 5 years | 5 years |
| $\delta_n^4$ | 0.025 | Job duration for type 4 | 5 years | 5 years |
| $\epsilon_1$ | 0.164 | Average skill level | 1.00 | 1.00 |
| $\epsilon_4$ | 50.14 | Debt-to-output-ratio | 0.40 | 0.40 |
| $\Pi_{1,4}^{\epsilon}$ | 0.002 | Income Gini index | 0.64 | 0.64 |
| $\Pi_{4,1}^{\epsilon}$ | 0.015 | Wealth Gini index | 0.82 | 0.84 |
| $\Pi_{1,1}^{\epsilon}$ | 0.965 | Persistence, $\rho_s$ | 0.91 | 0.91 |
| $\Pi_{2,2}^{\epsilon}$ | 0.977 | St.d of innovation, $\sigma_s$ | 0.20 | 0.20 |

Table 10: Dynamically Calibrated Parameters in the Zero Housing Economy

| Parameter | Value | Target |
|---|---|---|
| Adjustment cost, $\psi$ | 1.70 | Investment declines by 30% |
| Decreasing returns to scale in tradables, $\theta_0$ | 0.21 | Tradables-to-output-ratio increases by 4% |
| Wage elasticity, $\varphi^w$ | 0.55 | Ratio of wage change to output change, 0.45 |
| Matching elasticity in goods market, $\mu$ | 0.95 | TFP declines by 1.5% |