Asset price bubbles, sentiment shocks and business cycles

Shogo Miura

ULB

November 6, 2017

Abstract

This paper finds that there is a specific pattern in data which would be useful to detect an assets price bubble. The pattern is obtained by comparing the household’s asset value and nominal GDP and is observed commonly in the periods of Great Recession in U.S. and Land price bubble in Japan as well as Great Depression. This fact implies that severe economic contractions are often followed by assets price bubbles. Then, the paper presents a dynamic stochastic general equilibrium model which features sentiment shocks to household’s expectation and the utility function into which household’s wealth enters directly. The latter feature is known as a formation of ”spirit of capitalism”. By estimating the model using U.S. data, it is found that the sentiment shocks account for mild but non-negligible part of the fluctuations of macroeconomic variables. Finally, the conditional forecasts of the model show that a gap of household’s assets value and GDP growth may be a good measure to analyze a specific scenario such as the burst of asset price bubbles.

JEL classification: E32, E44, E47.

Keywords: DSGE models, Assets price bubbles, Bayesian estimation.

1 Introduction

Historically the bursts of asset price bubbles have been followed by the severe economic recessions. Examples include the stock bubble before Great Depression in 1930s in U.S, the real estate bubble before the economic slow down in 1990s in Japan, the housing bubble before Great Recession in late 2000s in U.S. and so on. From those examples, it seems true that the bursts of the asset price bubbles give deep damage to the real economy. However, the convention of wisdom is that even though it is true that the asset price bubbles are harmful for the economy, it is not possible to predict the bursts of such bubbles. This is because that the assets prices reflect not only the irrational factor which generates a bursting bubble, but also the fundamentals of the economy and the former is not observable in general. Thus, it is difficult to clarify whether an increase of assets value is due to a bubble which will burst afterward or just reflection of the real economy which will not burst. Needless to say, this imply that there is no measure to quantify how much bubble is contained in the actual asset prices.

*I am very grateful to Robert Kollmann for his invaluable guidance and support. I wish to thank Raf Wouters for his helpful comments and suggestions. I wish to thank the participants at doctoral workshop in Université catholique de Louvain, Belgium. All the errors are my own.
In this paper, I present a fact which seems to be useful to detect the asset price bubbles and quantify how much bubbles are within them. Even if it may not be possible to predict when the asset price bubbles burst with certainty in advance, the fact would be useful and improve to forecast it. Then, I build a DSGE model which is consistent with the fact and estimate the model using U.S. data. A noteworthy feature of the model is that it is based on near-rational expectations instead of rational expectations. The near-rational expectations adopted in this paper are affected by "sentiment shocks". Due to the sentiment shocks, economic agents’ expectation deviates from the rational expectation in short run. An economic interpretation of the sentiment shocks is simply that the economic agents such as households, firms, government and so on become sometimes optimistic or pessimistic about the future of the economy and those attitudes appear as the form of sentiment shocks. The estimation of the model provides how much such sentiment shocks are important in terms of business cycles of the economy and the movements of assets values.

Another feature of the model is the so-called "spirit of capitalism”. This means that the household’s utility function includes the assets value directly. Depending on the parameter values, consumption and the assets values can be non separable. Thus, the change of the assets values generates complementary effect on consumption. Under this assumption, the sentiment shocks can generate co-movement of major macroeconomic variables such as GDP, consumption, investment, values of the assets and so on. The intuition is simple. If the assets and consumption are complements to each other, sentiment shocks which induce the higher assets values increase the marginal utility from consumption. This provides the household an incentive to increase consumption which leads to the expansion of the economy.

The result of the model estimation shows that the sentiment shocks are important and play a non negligible role in terms of the business cycles fluctuations. For example, around 20 % of the fluctuation of GDP, 10% of consumption, 19 % of labor supply and 50 % of residential investment are driven by the sentiment shocks altogether. Also, the analysis of the historical shock decomposition shows that the sentiment shocks characterize the boom and bust cycle well which is observed around the financial crisis in 2007. Finally, I provide a scenario analysis of the burst of the assets bubbles which traced the financial crisis in 2007. The result of it shows that by and large, the model can replicate the magnitude of the shrink of the U.S economy.

1.1 Related literature

There are several related literatures. First, the flame work in this paper belongs to a strand of literature that uses DSGE models to analyze macroeconomic dynamics. In the literature, some of researches incorporate various asset price data. Iacoviello (2005) and Iacoviello and Neri (2010) build a DSGE model which includes housing sector and quantify the contribution of the housing market to business fluctuations. Liu et al. (2013) develop a DSGE model in which households use land as a collateral explain the co-movement between land prices and business investment. Jermann and Quadrini (2012) develop a model with debt and equity financing to explore how the dynamics of real and financial variables are affected by financial shocks. They find that financial shocks contributed significantly to the observed dynamics of real and financial variables. Using a DSGE model with banking sector, Iacoviello (2015) finds that financial shocks accounts for large part of output collapse during the Great Recession. The difference from this literature is that I incorporate household financial and nonfinancial asset values as data rather than house price or land price. This is because household assets values are more broad concept and would be suitable to assess comprehensively the effects of assets

---

1See Smets and Wouters (2007) and Lawrence J. Christiano and Evans (2005) for example
prices on household behavior as well as macroeconomy.

This paper is also related to non-rational expectation formation in DSGE models. Although there are many ways to formulate non rational expectations, one seminal way is to assume adaptive learning. Recent researches introduce adaptive learning to standard DSGE models and study its characteristics empirically. For instance, Slobodyan and Wouters (2012) evaluate the empirical performance of a medium-scale DSGE model with agents forming expectations using small forecasting models updated by the Kalman filter and find that the adaptive learning model fits the data better than the rational expectations model. Eusepi and Preston (2011) develop a model in which agents have incomplete knowledge about how market prices are determined and shifts in expectations of future prices affect dynamics. They show that in a real business cycle model, the theoretical framework amplifies and propagates technology shocks. Milani (2011) introduces expectational shocks into the New Keynesian model.

Related to the asset price literature, Adam and Marcet (2011) introduce ”internally rationality” to an asset pricing model and shows that the equilibrium stock price is then determined by investors’ expectations of the price and dividend in the next period, rather than by expectations of the discounted sum of dividends. Adam et al. (2016) show that consumption-based asset pricing models with time-separable preferences generate realistic amounts of stock price volatility if one allows for small deviations from rational expectations. The closest research to this paper is Arias (2016) which introduces sentiment shocks into a New Keynesian model and estimate it with Bayesian technique, although this paper focuses more on the role of asset prices.

There are a literature about the spirit of capitalism. Recent researches show that the spirit-of-capitalism hypothesis is useful in resolving a number of puzzles. For example, Bakshi and Chen (1996) examine a model where wealth enters directly into the utility function and argue that the spirit of capitalism seems to be a driving force behind stock market volatility and economic growth. Karnizova (2010) studies a model with the intrinsic desire for wealth and find that it brings a boom after a news shock which many existing models fail to predict. Michaillat and Saez (2014) develop a money-in-the-utility-function model where labor market is subject to matching frictions and real wealth enters the utility function and find that it generates steady-state equilibria with a liquidity trap, positive inflation, and labor market slack.

2 Fact

In this section, I present a stylized fact about the relationship between the household’s assets value and nominal GDP which would be useful to think about the boom and bust of the asset price bubbles.

2.1 The deviation of the household’s assets value is a useful signal for detecting a bubble?

Fig.1 shows the annual growth rates of the nominal GDP and the household’s total assets value in U.S. from 1946 to 2014. The household’s total assets consist of financial assets such as deposit, stock, security, pension, etc and nonfinancial assets such as house, real estate, land,

\footnotetext{2}{See Milani(2012) for a survey}
\footnotetext{3}{See Evans and Honkapohja (2001) and Evans and Honkapohja (2009) for detail.}
\footnotetext{4}{In a similar fashion, Milani (2011) studies the role of expectational shocks in a DSGE model.}
etc. As is shown in the figure, these two variables comove altogether in average except for the specific periods which are from 1995 to 2000 and 2003 to 2007. In those periods, the growth rate of household’s total assets value exceeds that of nominal GDP significantly. Needless to say, these two periods are the times just before the bursts of the Dotcom bubble or the Sub-prime loan bubble which led to severe economic recessions. In contrast, in around 1980 despite there was a large increase of household’s asset value which is comparable to 2004-2005, there was no big fall afterward as it was seen during 2007-2009.

{ Insert Figure 1 }

Thus, from this simple observation it may be possible to make a hypothesis:

**Hypothesis.** When there is a large, consecutive and long positive deviation of the growth rate of the household’s assets value from its fundamental value, a bubble exists inside of it and it will burst afterward. Also, there is a very close relationship between the fundamental value and GDP. The magnitude of the bubble depends on the magnitude of the deviation.

If this hypothesis is true, it is possible to detect the existence of bubble and estimate the magnitude of it in advance by observing the deviation of the assets value from GDP which is a proxy of the fundamentals, even if it is not possible to predict when the bubble bursts. It would be also possible to prepare for the burst of the bubble and take some measure in advance. Even if the hypothesis is not true, the deviation of household’s assets value seems to be very bad signal and should be carefully watched at least.

How much close is the relationship between the fundamentals of the assets and nominal GDP? Table.1 shows annual average growth rates (percent) and standard deviations of nominal GDP, household’s nonfinancial assets, financial assets and total assets. Whereas the annual growth rate of nominal GDP is 6.5 %, that of total assets value is 7.3 % which is 0.8 % higher than that of nominal GDP. This would imply that although the fundamental value of the assets is almost proportional to GDP and grows at almost same speed with GDP, there is still some gap between them. The gap may be just due to a measurement error. Even though there is a gap in the long run growth, as Fig 1 shows, average movement of the household’s assets value is very related to that of nominal GDP. Thus, it would be not a bad idea to assume that the movement nominal GDP approximate the fundamentals of the assets value.

As mentioned before, the household’s total assets consist of two kind of assets. One is financial assets and the other is the nonfinancial assets. Fig.2 shows the annual growth rates of household’s financial assets value and nominal GDP. Here, household’s financial assets include deposits, stocks, pension, bonds, asset backed securities and so on. The movement of household’s financial assets is almost same as that of household’s total assets value. However, as in the case of the household’s total assets value, it grows faster than the nominal GDP from 1995 to 2000 and 2003 to 2007. Therefore, it would be possible to claim that there is a bubble in the financial assets part.

{ Insert Figure 2 }

On the other hand, Fig.3 shows the annual growth rate of household’s nonfinancial assets value and the nominal GDP. The household’s nonfinancial assets consist of housing and some other stuff. However, since more than 90 % of the nonfinancial assets are housing, it is possible to treat nonfinancial assets as housing. As is clear in the figure, from 1998 to 2006 the growth rate of nonfinancial assets exceeds that of nominal GDP significantly and constantly. Even when the Dotcom bubble busted, the household’s nonfinancial assets value did not fall much. From the figure, it may be possible to say that the bubble in the nonfinancial assets had started to grow in 1998, not around 2004 from when the sub-prime lending started to rise.
Fig. 4 presents the annual growth rates of housing price and nonfinancial assets. Clearly, the nonfinancial assets are almost driven by housing price rather than the quantity of housing. Thus, it is possible to say that the increase of housing price lead to the increase of the household’s nonfinancial assets almost one to one.

Fig 5 shows the annual growth rates of the household’s net worth and nominal GDP. As is shown, the household’s net worth moves almost together as the household’s total assets and grows faster than nominal GDP during a bubbly era. This phenomenon is also true in the case where other sectors such as government sector, corporate sector and foreign sector are considered about. Fig .6 shows the annual growth rates of U.S. national net worth and nominal GDP. The movement of it almost coincides to that of the household’s net worth.

Although recent researches argue that credit boom is important in detecting bubbles, at least from those figures, to focus on asset side or net worth seems to be more useful than focus on the credit if the credit is defined as liability side.\(^5\) It could be said that when bubble starts appear, the asset values grow faster than the liability and the growth rate of net worth exceeds that of fundamentals, i.e., GDP

2.2 The Japan’s land price bubble in 1990s is same type of the bubble which the U.S. experiences before Great Recession?

So far, the analysis has been focused on only U.S case. However, there are many other cases of asset bubbles. In this subsection, I analyze the Japan’s land price bubble in 1990s and study whether there is a same pattern in the data as is seen in the previous subsection.

Fig 7 shows the annual growth rates of the household’s total assets and nominal GDP in Japan from 1980 to 2009. Clearly, the former exceeds the latter significantly from 1986 to 1989 after which the bubble bursts in 1991. Other than that period the household’s total assets almost comoves with the nominal GDP. This pattern is sames as the U.S case.

Fig 8 shows the annual growth rates of household’s financial assets and nominal GDP in Japan from 1980 to 2009. Until 1989, the value of household’s financial assets grows more than nominal GDP. After the bubble burst, the value falls temporarily but then starts to rise again and in average it grows more than nominal GDP.

Fig. 9 shows the annual growth rates of household’s nonfinancial assets and nominal GDP in Japan from 1980 to 2009. As in the case of U.S, from 1986 to 1989 there is a big rise in the value of nonfinancial assets compared to nominal GDP. After the burst of the bubble, the value of the nonfinancial assets started to decrease and does not rise again until 2006. The decrease of the nonfinancial assets cancels out the increase of the financial assets after the burst of the bubble, leading to almost zero increase of the total assets in average.

\(^5\)Regarding the role of credit in terms of bubbles, see Jordà et al. (2015). They define bank loan as credit and show that credit boom makes some bubbles more dangerous.
In the case of Japan, it looks that the effects of bursting bubble last very long compared to the U.S. However, since the working population of Japan began to decrease from 1998 and there might be also the effects of liquidity trap, it would be difficult to assess how much the burst of the bubble affect the stagnation of Japan’s economy afterward. One can say is that there is a same pattern between U.S case and Japan’s case. This can suggest a hypothesis that there is a common pattern, i.e. a deviation of the growth rate of household’s assets value from nominal GDP, when a assets bubble start to arise.

2.3 The house price bubbles in Euro area

The gap between nonfinancial assets and nominal GDP is observed also in Euro area around financial crisis era. Fig 10 represents the growth rates of residential property prices which is treated as a proxy of household’s nonfinancial assets value and nominal GDP for Euro area from 1996 to 2015.

As is clear in the figure, there had been a positive deviation of the former compared to the latter before the crisis and such positive gap is canceled out by the negative gap from 2010 to 2015. Thus, it may be possible to say that there was another asset price bubble in Euro area as in the case of U.S. The burst of the bubble might be an indirect cause of the subsequent debt crisis in Euro area.

2.4 Was the Great Depression in U.S mainly due to the assets price bubble ?

So far, I have investigated the recent U.S case and Japan’s case. In both cases, it seems that there is a clear deviation of the growth rate of assets value from nominal GDP before the economy fall down severely. Then, natural question is whether there is a same pattern in the case of the Great Depression in 1930s in U.S. It is well known that there was a huge soring in stock prices before the economy crashed. Does it means that there was a huge rise on the household’s assets value compared to nominal GDP as there are in previous cases ? Since there is no data about the value of the household’s assets, I treat the annual growth rate of S & P index as a proxy for the household’s financial assets and the U.S. Case Shiller Home Price Index as a proxy for the household’s nonfinancial assets. Then I compare them with the growth rate of nominal GDP for U.S. from 1981 to 1945.

Fig.11 shows the result of the former. As is seen in the figure, there is a consecutive and significant deviation of S & P index compared to nominal GDP from 1925 to 1929. At the peak in 1929, the growth rate of S & P index records around 41 percent, while the growth rate of nominal GDP is only around 6.4 percent. Thus, although the S & P index dose not represents the household’s financial assets itself, the possibility that the household’s financial assets grows

---

6There are a huge literature about the causes of the Great Depression. Standard views include the burst of the stock market, the decline of the money supply due to gold standard, debt deflation, a shift in expectation, productivity shock and so on.

faster than nominal GDP before the bubble bursts seems high. One thing to note is that in the case of the Great Depression, the magnitude of the bubble in financial assets looks high compare to the Great Recession, because the annual growth rate of financial assets in the Great Recession is lower than 15% at most.

Fig. 12 shows the annual growth rates of the U.S. Case Shiller Home Price Index and the nominal GDP. Both variables seem to comove to some extent except for war periods. Interestingly, unlike to the recent U.S. and Japan’s cases, there is no significant positive deviation of the home price index from nominal GDP growth before the economy goes into recession. In fact, the growth rate of the home price index looks lower than that of nominal GDP in the boom periods of 1920s - 1930s. From this fact, it may be able to say that Great Depression is associated with a stock price bubble or a bubble in household’s financial assets rather than a housing price bubble or a bubble in household’s nonfinancial assets which was seen in Great Recession.

However, White (2014) argue that there may be a strong downward bias on Case-Shiller Home Price index in earlier years. Also, Nicholas and Scherbina (2013) shows that at least in Manhattan, real prices rose around 32 percent between 1920 and 1929 before falling to 37 percent in 1932. Thus, it would be difficult to assess how much bubble there was in household nonfinancial assets correctly.

2.5 A summary of the analysis

In the above discussion, three bubble cases - Subprime loan bubble in U.S, Land price bubble in Japan and Great Depression in U.S. - are reviewed. In the former two cases, there are significant increases of household’s financial and nonfinancial asset value compared to the nominal GDP before the bubble burst. In the latter, there is a similar significant increase of S & P index, which could be treated as household’s financial assets, compared the nominal GDP. Therefore, the comparison of the growth rate of household’s assets with the growth rate of nominal GDP would be very useful to predict an asset price bubble and the bursting of it. From the Figures, more than two consecutive years deviation of the assets value from the nominal GDP seems to be very bad signal. In the recent U.S. mortgage bubble case, two consecutive years deviation of the household assets is observed in 2004. In this point, if the above fact is found, it may be possible to predict the bubble and take some measure to mitigate the negative shock.

3 The model

There is a representative household who maximize the expected present discounted value of utility. The household’s preference is defined over consumption goods $C_t$, hours worked $N_t$, the value of household’s nonfinancial assets $q_h^t H_t$ and the value of household’s financial assets $q_s^t S_t + B_t$. Here, $q_h^t$ is the price of household’s nonfinancial assets and $H_t$ is the quantity of them. The household’s financial assets are assumed to consist of the value of stocks $q_s^t S_t$ where $q_s^t$ is

---

the price of stocks and $S_t$ is the quantity of them, and the loan to firms $B_t$.\footnote{In data, households’ financial assets include stocks, deposits, pension funds, bonds, other financial securities etc.} Thus, the so-called “spirit of capitalism” formation which is that the household’s wealth enters her utility function directly is explicitly assumed in the model. The household’s expected utility is represented as follows:

$$\tilde{E}_t \sum_{s=0}^{\infty} \beta^s \left[ \frac{X_{t+s}^{1-\sigma}}{1-\sigma} - \frac{\chi_t}{1+\psi} N_{t+s}^{1+\psi} \right]$$

(1)

where

$$X_t = \left[ \omega_c C_t^{\frac{\eta+1}{2\eta}} + \omega_h (q_t^h H_t)^{\frac{\eta-1}{2\eta}} + \omega_s (q_t^s S_t + B_t)^{\frac{\eta-1}{2\eta}} \right]^{\frac{2}{\eta-1}}.$$  (2)

$\tilde{E}_t$ denotes the household’s subjective expectation at time $t$, $\sigma$ is the inverse of the elasticity of intertemporal substitution and $\eta$ is the elasticity of substitution for each component. The three components become perfect substitutes as $\eta \to \infty$ and perfect complements as $\eta \to 0$. Taking the limit as $\eta \to 1$ yields the Cobb–Douglas specification and if $\eta = 1/\sigma$, the utility function becomes separable. $\chi_t$ is the parameter for the disutility from labor and it equals $l_t^1$. $v$ is a labor-augmented technology growth rate. This imply that the model is consistent with the balanced growth. $l_t$ is an exogenous labor supply shock and follows a stochastic process:

$$\ln l_t = (1 - \rho_t) \ln l + \rho_t \ln l_{t-1} + \epsilon_t.$$  (3)

The household’s budget constraint is given by

$$C_t + q_t^h (H_t - (1 - \delta^h) H_{t-1}) + B_t + q_t^s S_t = W_t N_t + R_{t-1} B_{t-1} + (q_t^s + d_t) S_{t-1} + V_t$$  (4)

where $\delta^h$ is the depreciation rate of nonfinancial assets, $W_t$ real wage, $R_t$ real interest rate in period $t$, $d_t$ is dividends for stocks and $V_t$ is other transfers from the firm. The household chooses $C_t$, $H_t$, $N_t$, $S_t$ and $B_t$ to maximize the expected utility. The household’s first order conditions are denoted as follows:

$$X_t^{\frac{1}{\eta-\sigma}} \omega_c C_t^{\frac{\eta-1}{\eta}} = \lambda_t$$  (5)

$$X_t^{\frac{1}{\eta-\sigma}} \omega_h (q_t^h)^{\frac{\eta-1}{\eta}} = \lambda_t q_t^h + \beta \tilde{E}_t \left[ \lambda_{t+1} q_{t+1}^h (1 - \delta) \right] = 0$$  (6)

$$\chi_t N_t^{\psi} = \lambda_t W_t$$  (7)

$$X_t^{\frac{1}{\eta-\sigma}} \omega_s (q_t^s + B_t)^{\frac{\eta-1}{\eta}} q_t^s = \lambda_t q_t^s + \beta \tilde{E}_t \left[ \lambda_{t+1} (q_{t+1}^s + d_{t+1}) \right] = 0$$  (8)

$$X_t^{\frac{1}{\eta-\sigma}} \omega_s (q_t^s + B_t)^{\frac{\eta-1}{\eta}} = \lambda_t + \beta \tilde{E}_t [\lambda_{t+1} R_t] = 0$$  (9)

### 3.1 The representative firm

The representative firm produces final goods using capital, labor, and nonfinancial assets for the firm. The production function of the firm is given by

$$Y_t = A_t ((u_t K_{t-1})^\xi H_{t-1}^{1-\xi})^\alpha (v^\prime N_t)^{1-\alpha}.$$  (10)
where $Y_t$ denotes output, $K_{t-1}$ capital, $H_{e,t-1}$ nonfinancial assets held by the firm, $N_t$ aggregate labor supply, and $u_t$ the level of capital utilization respectively. The total factor productivity $A_t$ follows a stochastic process:

$$\ln A_t = (1 - \rho_A) \ln A + \rho_A \ln A_{t-1} + \epsilon^a_t$$  \hspace{1cm} (11)

The firm’s profits at period $t$ is defined as $\pi_t$. A fraction $\kappa$ of $\pi_t$ are distributed as dividends to the stocks so that $(1 - \kappa)\pi_t = d_t$ holds. The rest of the profit is transferred to the household directly so that $(1 - \kappa)\pi_t = V_t$ holds.\footnote{This represents extra payments for employees and employers such as bonus, benefits, insurance and so on.} Following Kiyotaki and Moore (1997) and Iacoviello (2005), the firm faces a collateral constraint and the maximum amount of the firm’s loan $B_t$ is bound by $E_t \theta_t q_{t+1} H_{e,t}$, where $q_{t+1}$ is the price of general nonfinancial assets which is discussed later and $H_{e,t}$ is the quantity of nonfinancial assets held by the firm.\footnote{It is possible to assume that the firm could also use its capital $K_t$ as a collateral. However, in reality it is more common to use nonfinancial assets such as buildings, offices, lands etc as a collateral. Therefore, in the model it is assumed that the firm use only nonfinancial assets as a collateral.}

The firm maximizes $\pi_t$ subject to the budget constraint, production function, collateral constraint and capital accumulation equation. The firm’s optimization problem is represented as

$$\max \sum_{s=0}^{\infty} \beta^s \pi_{t+s}$$

subject to

$$\pi_t + q_t^e (H_{e,t} - (1 - \delta^h) H_{e,t-1}) + R_{t-1} B_{t-1} + \zeta u_t^h K_{t-1}$$
$$= Y_t - W_t N_t + B_t - \left[ 1 + \frac{\phi}{2} \left( \frac{I_t}{I_{t-1}} - v \right)^2 \right] I_t$$

$$Y_t = A_t (K_{t-1}^\xi H_{e,t-1}^{1-\xi})^\alpha N_{t-1}^{1-\alpha}$$  \hspace{1cm} (14)

$$B_t \leq \theta_t E_t q_{t+1} H_{e,t}$$  \hspace{1cm} (15)

$$K_t = (1 - \delta) K_{t-1} + x_t^i I_t$$  \hspace{1cm} (16)

where $q_t^e$ is the price of firm-specific nonfinancial assets, $q_t$ is the price of general nonfinancial assets , $I_t$ investment and $x_t^i$ is an investment specific technology shock and follows a stochastic process:

$$\ln x_t^i = (1 - \rho_i) \ln x_t^i + \rho_i \ln x_{t-1}^i + \epsilon^i_t$$  \hspace{1cm} (17)

The FOCs of the firm are given as follows:

$$1 = \lambda_{e,t}$$  \hspace{1cm} (18)

$$\beta_e \alpha (1 - \xi) \dot{E}_{t} \left[ \lambda_{e,t+1} \frac{Y_{t+1}}{H_{e,t}} \right] - \lambda_{e,t} q_t^e - \beta_e \dot{E}_{t} \left[ \lambda_{e,t+1} q_{t+1}^e (1 - \delta) \right] - \beta_e \dot{E}_{t} \left[ \mu_{e,t+1} \theta_t E_t (q_{t+1}) \right]$$

$$\beta_e \dot{E}_{t} \left[ \frac{Y_{t+1}}{K_t} \right] - \gamma_t + \beta_e \dot{E}_{t} \left[ \gamma_{t+1} (1 - \delta) \right] + \beta_e \theta_k \dot{E}_{t} \left[ \mu_{e,t+1} \right] + \beta_e \dot{E}_{t} \left[ \mu_{e,t+1} \right] = 0$$  \hspace{1cm} (21)

$$-\lambda_{e,t} \left[ 1 + \phi \left( \frac{I_t}{I_{t-1}} - v \right)^2 + \phi \left( \frac{I_t}{I_{t-1}} - v \right) \frac{I_t}{I_{t-1}} \right]$$

\hspace{1cm} (19)
general nonfinancial assets is adjustment costs. The cost to produce. The developers create the nonfinancial assets for the household and the firm with different following condition in the steady state: It is assumed that \( \beta < \beta \) and the collateral constraint holds with equality in the neighborhood of the steady state. To normalize the steady state value of \( u_t \) to 1, \( \zeta \) is assumed to meet the following condition in the steady state:

\[
\zeta = \alpha \xi Y \tau K
\]

where \( Y \) and \( K \) denote the steady state values of output and capital.

### 3.2 General nonfinancial assets providers and developers

There are nonfinancial assets providers who produce general nonfinancial assets from final goods. Then, they sell those assets to the developers. The cost to produce \( I^h_t \) unit of general nonfinancial assets is

\[
q_t = 1 + \frac{\phi_h}{2} \left( \frac{I^h_t}{I^h_{t-1}} - v \right)^2 + \phi \left( \frac{I^h_t}{I^h_{t-1}} - v \right) \frac{I^h_t}{I^h_{t-1}} - \hat{\epsilon}_t \Lambda_{t,t+1} \phi \left( \frac{I^h_{t+1}}{I^h_t} - v \right) \left( \frac{I^h_{t+1}}{I^h_t} \right)^2
\]

\( q_t^h = q_t + \frac{\phi_h}{2} \left( \frac{I^h_t}{I^h_{t-1}} - v \right)^2 + \phi \left( \frac{I^h_t}{I^h_{t-1}} - v \right) \frac{I^h_t}{I^h_{t-1}} - \hat{\epsilon}_t \Lambda_{t,t+1} \phi \left( \frac{I^h_{t+1}}{I^h_t} - v \right) \left( \frac{I^h_{t+1}}{I^h_t} \right)^2 \)

\( q_t^e = q_t + \frac{\phi_e}{2} \left( \frac{I^e_t}{I^e_{t-1}} - v \right)^2 + \phi \left( \frac{I^e_t}{I^e_{t-1}} - v \right) \frac{I^e_t}{I^e_{t-1}} - \hat{\epsilon}_t \Lambda_{t,t+1} \phi \left( \frac{I^e_{t+1}}{I^e_t} - v \right) \left( \frac{I^e_{t+1}}{I^e_t} \right)^2 \)

where \( \Lambda_{t,t+1} \) is a stochastic discount factor.

\[12\text{Households purchase the nonfinancial assets such as house, while firms purchase the non financial assets such as building, offices and factory.}\]
### 3.3 Market clearing

The goods market clearing condition is as follows:

\[
C_t + \left[ 1 + \frac{\phi}{2} \left( \frac{I_t}{I_{t-1}} - v \right)^2 \right] I_t + \left[ 1 + \frac{\phi_g}{2} \left( \frac{I^h_t}{I^h_{t-1}} - v \right)^2 \right] I^h_t + \left[ 1 + \frac{\phi}{2} \left( \frac{I^{h,e}_t}{I^{h,e}_{t-1}} - v \right)^2 \right] I^{h,e}_t + G_t = Y_t
\]

where \( G_t \) is the government spending and it follows a stochastic process:

\[
\ln G_t = (1 - \rho_g) \ln G + \rho_g \ln G_{t-1} + \epsilon^g_t
\]

The demand for nonfinancial assets equal to the supply:

\[
I^h_t = I^{h,h}_t + I^{h,e}_t = H_t - (1 - \delta^h)H_{t-1} + H_{e,t} - (1 - \delta^h)H_{e,t-1}
\]

### 3.4 Near-rational equilibrium

So far, it is assumed that the economic agents in the model behave according to their subjective beliefs. In this section, it is discussed how they formulate their subjective beliefs. Suppose that an agent \( i \)'s subjective expectation regarding a variable \( X_{t+1} \) is expressed as \( \hat{E}_t [X_{t+1}|\Omega^i_t] \) given his information set \( \Omega^i_t \) in period \( t \), then it is represented as follows:

\[
\hat{E}_t \left[ X_{t+1}|\Omega^i_t \right] = D^i_t(X_{t+1}, \Omega^i_t)E_t \left[ X_{t+1}|\Omega^i_t \right]
\]

where \( D^i_t(X_{t+1}, \Omega^i_t) \) is a "sentiment shock" and follows a stochastic process. Thus, the subjective expectation is affected by exogenous shocks and deviates from rational expectation. However, in average the subjective expectation coincides to rational expectation. Actually, mathematical expectation value of the subjective expectation equals to the rational expectation:

\[
E_t \left[ \hat{E}_t \left[ X_{t+1}|\Omega^i_t \right] \right] = E_t \left[ D^i_t(X_{t+1}, \Omega^i_t)E_t \left[ X_{t+1}|\Omega^i_t \right] \right] = E_t \left[ X_{t+1}|\Omega^i_t \right]
\]

The interpretation of the sentiment shock \( D^i_t(X_{t+1}, \Omega^i_t) \) is simply that the economic agents sometimes become optimistic or pessimistic about the future for some reason and they overestimate or underestimate the future values of macroeconomic variables. Such sentiment shocks affect the the economy through the equations which represent the agents’ behavior. For example, the Euler equations of the household are affected by sentiment shocks in fact. It would be possible to interpret sentiment shocks as a kind of demand shocks.

I assume that only the representative household is near-rational and affected by sentiment shocks. In other words, the representative firm, nonfinancial assets providers and developers formulate rational expectation and not affected by sentiment shocks. Thus, there are three

---
13 The formulation of near-rational expectation in this paper is close to Arias (2016), although there is no learning in this paper. Also, Gabaix (2016) and Woodford (2013) study New keynesian models with boundedly rational expectation in alternative fashions.

14 The purpose of this assumption is to focus on the role of sentiment shocks in the Euler equations. Of course, it is possible to examine the role of sentiment shocks in other sectors.
sentiment shocks in the model which work through Euler equations of the representative household. The Euler equations for the household which include sentiment shocks explicitly can be rewritten as follows:

\[ X_t^{\frac{1}{\eta^h}} \omega^h(q_t^h)^{\varsigma_h} - \lambda_t q_t^h + \beta D_t^h E_t \left[ \lambda_{t+1} q_{t+1}^h (1 - \delta) \right] = 0 \] (37)

\[ X_t^{\frac{1}{\eta^s}} \omega^s(q_t^s + B_t)^{\varsigma_s} - \lambda_t q_t^s + \beta D_t^s E_t \left[ \lambda_{t+1} (q_{t+1}^s + d_{t+1}) \right] = 0 \] (39)

\[ X_t^{\frac{1}{\eta^b}} \omega^b(q_t^b + B_t)^{\varsigma_b} - \lambda_t + \beta D_t^b E_t \left[ \lambda_{t+1} R_t \right] = 0 \] (40)

The sentiment shocks are assumed to follow AR(1) process for each variable:

\[ \ln D_t^X = (1 - \rho_X) \ln D_t^{X-1} + \rho_X \ln D_t^{X-1} + \epsilon_t^X \] (41)

where \( X \in \{q, s, b\} \).

The sentiment shocks for the assets are equivalent to the so-called “risk premium” shocks mathematically. However, the interpretation of the sentiments shocks are different from risk premium shocks, since the sentiment shock are based on the near-rationality.\(^{15}\)

4 Estimation

The model is estimated by Bayesian method. The quarterly U.S. time series data which consist of real GDP, consumption, business fixed investment, residential investment, hours worked, household’s nonfinancial assets, household’s financial assets and housing price index for the period of 1975:Q2-2015:Q2 is used for the estimation. Detailed descriptions of the data and the measurement equations are provided in Appendix A.

The exogenous shocks consist of aggregate technology shock, investment-specific technology shock, housing-specific technology shock, labor supply shock, government spending shock and three sentiment shocks.

4.1 Calibration and Priors

Some parameters are calibrated in advance. The discount factor of the household \( \beta \) is set at 0.99. The depreciation rates of physical capital and nonfinancial assets, \( \delta \) and \( \delta_h \) are set at 0.025 and 0.03 respectively. \( \kappa \) is set to 0.21.\(^{16}\) The steady state value of the government share in GDP \( \bar{g} \) is selected to 0.18. Those values are standard in the existing literature.

Prior distributions for all other parameters are summarized in Table 2 and Table 3. The parameters for preference of consumption and nonfinancial assets, \( \omega_c \) and \( \omega_h \), are set at 0.6 and 0.2. These values are selected in the way that the steady state GDP share of residential investment become around 4% which is consistent with data. The parameter for preference of financial assets \( \omega_s \) is determined from Eq.(7) in the steady state, if the ratio between financial assets and GDP \( q^s/Y^gdp \) is given and vice versa. Here, it is assumed that the prior distribution is provided for only \( q^s/Y^gdp \). This implies that \( \omega_s \) is treated as an endogenous variable rather than a parameter. This is because it is not possible to solve Eq.(7) for \( q^s/Y^gdp \) given \( \omega_s \) analytically. Therefore, in this estimation \( \omega_s \) is determined given \( q^s/Y^gdp \) rather than determining \( q^s/Y^gdp \).

\(^{15}\)For the different interpretation of the risk premium shocks, see Fisher (2015).

\(^{16}\)Due to a collinearity problem, it is not possible to identify \( \kappa \). This value of \( \kappa \) implies 0.2 of the prior mean of \( \omega_s \) which is same as \( \omega_h \), given the prior mean of \( q^s/Y^gdp \).
given $\omega_s$. The prior mean of $q_s/Y^{gdp}$ is set at 2.4 which is consistent with data. The elasticity of substitution $\eta$ is set at 0.3. The inverse of intertemporal substitution $\sigma$ is set to 1. The Frisch elasticity of labor supply is set at 0.3.

The discount factor of the firm is set at 0.975. The parameter for the collateral constraint $\theta$ is set at 0.8. The parameters for input share in production, $\alpha$ and $\xi$, are set at 0.24 and 0.9 respectively. Both the adjustment costs of capital and the adjustment costs for developers are set at 10. The adjustment costs for the nonfinancial assets providers is set at 20. Capital utilization rate is set at 0.01. The steady state growth rate of GDP and the steady state value of labor supply, $\ln v$ and $\ln j$ are set to match the sample means of each data.

5 The result

In this section, I study the implications of the estimated model. To examine how sentiment shocks affect the economy, the impulse responses are reviewed. Also, I analyze the forecast error variance decomposition to investigate what shocks are important in terms of driving business cycles.

5.1 Posteriors and business cycle properties

The last three columns of Table 2 and Table 3 report the means and 5 % and 95 % of the posterior distribution for the estimated model parameters. For other parameters, the result of estimation seems to be standard.

Table 4 shows the posterior means of the business cycle statistics from the estimation and the actual values of them from data. Regarding the variances and correlations of the variables, the model fit to the data well. One thing to note here is that from the data, the so-called "wealth effects", i.e., the positive effects of household’s assets values on consumption, is observed. Actually, the correlation coefficients between household’s nonfinancial assets and financial assets value are positive and 0.33 and 0.23 respectively. This is consistent with the empirical studies about the wealth effects.17

Regarding the autocorrelations, some variables such as GDP, consumption, nonfinancial assets and housing price do not fit well to the data. Especially, the autocorrelations of nonfinancial assets and housing price in the actual data are much larger than the estimated ones. This may be due to that the model does not incorporate nominal rigidities which are known to generate larger persistence of endogenous variables. However, by and large the model’s ability to replicate the actual data is not bad.

5.2 Impulse response analysis

Figure 13-20 shows the estimated impulse responses to the exogenous shocks. The gray shaded areas show 90 % confidence interval. The shocks consist of five supply-side shocks (aggregate technology shock, investment-specific technology shock, housing-specific technology shock, labor supply shock and government spending shock) and three demand shocks (sentiment shocks in the household).

Fig 13 and 14 represent the impulse responses to the aggregate technology shock and investment-specific technology shock. As is the case with many researches in the existing literature, those two shocks bring comovement of major macroeconomic variables such as GDP,

---

17See for example Campbell and Cocco (2007), Case et al. (2005) and Mian et al. (2013)
consumption, investment and so on. In addition to that, a positive aggregate technology shock also increases financial and nonfinancial assets value of households, and housing price and stock price. The effect of investment-specific technology shock is similar to that of aggregate technology shock, except that it decrease the nonfinancial assets price at the impact.

Fig 15 - 17 represent the impulse responses to the housing-specific technology shock, labor supply shock and government spending shock. Since a positive housing-specific technology shock implies the decrease of the cost to obtain a unit of housing, it generates an expansion of economy generally although the business fixed investment decrease after the impact. A positive labor supply shock brings a boom in terms of all the variables. The propagation mechanism of the labor supply shock is same with the existing business cycles literature although it’s effect is amplified through the spirit of capital channel in this model.

Fig 18 shows the impulse responses to the positive first sentiment shock. First sentiment shock generates the dynamics of the economy through the household’s Euler equation with respect to nonfinancial assets. The household’s higher expectation for the value of nonfinancial assets tomorrow induces her to store more nonfinancial assets. This raises the value of the assets. Due to the complement effect of the value of the assets for consumption the household also consumes more. Thus, it stimulates output and investment. Since the household prefer purchasing more nonfinancial assets to purchasing stocks, the value of financial assets decreases. Although this brings a negative complement effect on consumption, the positive effect of nonfinancial assets is dominant in this case.

One thing to note here is that the first sentiment shock generates more volatile movement on nonfinancial assets than the aggregate technology shock. For example, while one standard deviation technology shock generates around 0.16 % positive deviation of GDP and 0.2 % positive deviation of nonfinancial assets value, the one standard deviation first sentiment shock generates around 0.06 % positive deviation of GDP and 0.6 % positive deviation of nonfinancial assets value. Thus, it would be the case that the first sentiment shock contributes to explain the fact that nonfinancial assets value is more volatile than GDP which is shown in Table 1.

Fig 19 shows the impulse responses to the positive second sentiment shock. Second sentiment shock works through the household’s Euler equation for stocks. The household expects higher value of financial assets tomorrow so that the price of the stocks become high. Since the stocks are complement of consumption, the household increases consumption, leading to the economic expansion. This mechanism is similar to the case of nonfinancial assets. Third sentiment shock works through the household’s Euler equation with respect to the loan to the firm.

Fig 20 shows the impulse responses to the positive third sentiment shock. The third sentiment shock works through the household’s Euler equations for a loan. This shock is captured as a positive increase of tomorrow’s Lagrange multiplier for some reason. It implies that the household expects higher marginal utility from the relaxation of the budget constraint tomorrow. Thus, the household has an incentive to work and save more today which lead to the expansion of the economy.
5.3 Variance decomposition

Table 5 shows the asymptotic forecast error variance decomposition. Regarding GDP, the labor supply shock explains around 37% of the movement of it, while the aggregate technology shock, government spending shock and first sentiment shock explain around 18%, 15% and 13% respectively. Those shocks also explain around 90% of the movement of consumption together. The movement of labor supply is almost driven by the labor supply shock, government spending shock and first sentiment shock. The movement of business investment is almost accounted for by the investment-specific shock.

The housing-specific technology shock, third sentiment shock and first sentiment shock are the main drivers of the movement of the residential investment and more than 90% of it is explained by them. The financial assets value of the households is almost driven by second sentiment shock and it accounts for more than 80% of the movement. The second sentiment shock also explain more than 90% of the movement of the stock price. Although the second sentiment shock accounts for a large part of the movements of stock price or financial assets, it dose not contribute to the movements of output, consumption, investment and labor supply at all. This implies that the wealth effect of the financial assets is not so much large. The nonfinancial assets value is almost driven by first sentiment shock and it account for more than 80% of the movement though it does not account for housing price dynamics.

Overall, the result shows that sentiment shocks play a non-negligible role in accounting for the movements of the important macroeconomic variables such as GDP, consumption, labor supply, residential investment and so on, whereas typical supply-side shocks (aggregate technology shock, investment-specific technology shock, housing-specific technology shock, labor supply shock and government spending shock) are still powerful in explaining the movements.

How important were the sentiment shocks in explaining the recent U.S. financial crisis? Figure 24 shows a historical decomposition of output from 2002Q1 to 2013Q2. It is clear that during Great Recession, the sentiment shocks contribute to the decrease of output significantly. Especially, negative first sentiment shock and third sentiment shock push down output growth during the crisis. Also, it is clear that before the crisis - from 2003 to 2006 - the positive sentiment shocks push up output growth. Thus, it can be said that the positive sentiment shocks caused the asset price bubble and economic expansion before the crisis, but since those positive sentiment shocks reflected too much optimistic expectation about the future assets prices, they were canceled out by the subsequent negative sentiment shocks, which triggered a burst of the asset price bubble brought Great Recession.

5.4 How the “spirit of capitalism” formation affects the transmission of the exogenous shocks?

In this subsection, I investigate how “spirit of capitalism” formation, i.e. the existence of the assets values in the household utility function, affects the transmission of the exogenous shocks.

Figure 21 shows the impulse responses to the first sentiment shock under the different values of $\omega_h$. The benchmark model is the estimated model where all parameters are set to the posterior means. The posterior mean of $\omega_h$ is 0.19 and high and low values of $\omega_h$ is set to 0.0001 and 0.50 respectively. As is clear in the figure, the higher $\omega_h$ becomes, the larger the effects of the shock are. This is because that the large value of $\omega_h$ implies the large complement effect from nonfinancial assets to consumption. Thus, when $\omega_h$ is high, the effects of first sentiment shock are...
shock is amplified. If $\omega_h$ is zero, i.e. if there is no nonfinancial assets term in the household’s utility function, the first sentiment shock does not affect the economy at all.\footnote{Strictly speaking, when $\omega_h$ is zero, the household does not have an incentive to hold the nonfinancial assets so that there is no Euler equation for the nonfinancial assets in the first place.}

Figure 22 shows the impulse responses to the second sentiment shock under the different values of $\omega_s$. As in the previous case, the higher $\omega_s$ becomes, the larger the effects of the shock are. The amplification mechanism of $\omega_s$ is same as $\omega_h$ and high value of it implies high complement effect to consumption.

Although the values of $\omega_h$ and $\omega_s$ are important in terms of amplifying the effects of the first and second sentiment shock, they have little effects on the amplification of the other exogenous shocks quantitatively. For example, Figure 23 shows the impulse responses to the technology shock under high and low value of $\omega_h$. As the figure shows, there is very little effects from the changes of $\omega_h$ value. This applies to other exogenous shocks. In other words, $\omega_h$ only affect the first sentiment shock quantitatively at least in the benchmark setting.\footnote{Of course, the effects of $\omega_h$ depends on the other parameters values and it is possible that the change of $\omega_h$ has bigger effects on the transmission of other shocks.}

\section{Scenario analysis of the effects of bursting bubbles}

In this section, I study a specific scenario of the bursting bubbles by conducting a conditional forecast. As is shown in Figure 4 and Figure 5, the household financial assets and household nonfinancial assets has started to expand faster than GDP growth from around 1996. This would reflect the optimistic expectation of the households about the future assets prices and that a bubble started to accumulate then. If the values of household financial assets and household nonfinancial assets in 1996 are supposed to 1, they peak at about 1.15 and 1.27 respectively in 2006, whereas GDP is only 1.08 if GDP in 1996 is supposed to be 1. Thus, it is possible to consider a scenario that those assets values decrease afterward enough to that the gap of growth rate between the assets values and GDP is canceled out. In other words, the specific scenario studied here assesses what happens if that the seemingly accumulated bubble bursts in a specific period. Of course, this is just a scenario and it is possible that the bubble does not burst in that time and still keep growing. The data used is same as in the previous section.

Figure 21 - 26 presents the conditional and unconditional forecasts of GDP, consumption, business investment and residential investment at the point of 2007Q4 given that the household’s financial and nonfinancial assets values continue to decrease at the rate of -1\% for subsequent two years.\footnote{The forecasts here are based on the result of estimation for the data from 1975Q2 to 2007Q4.} As the controlled exogenous shocks, labor supply shock and first sentiment shock are selected since they are especially important drivers of various macroeconomic variables. Not surprisingly, compared to the unconditional forecasts, the conditional forecasts predicted severe recessions. GDP, consumption and business investment are all expected to decrease significantly as the household assets values collapses.

\footnote{The forecasts here are based on the result of estimation for the data from 1975Q2 to 2007Q4.}
This exercise does not mean that it was actually possible to predict the recession in 2007, since there is a possibility that such episode did not happen at all and the assets values still continued to grow. However, this kind of exercise could bring an estimates of the effects of the bursting asset bubbles. Such information seem to be useful especially when there is a suspicion of asset bubbles.

If it is true that the household’s assets values grow at the same speed of GDP in the long run, the positive deviation of it must be canceled out at some point. What happens if such cancellation happen today or tomorrow? Conducting a conditional forecasts might be able to answer such question. One thing to note is that as of 2006 or 2007, the household assets values had grown greater enough than GDP, the bursting of the bubbles would realize sooner or later. In this sense, it may be desirable to do a scenario analysis if there is a bad signal, i.e. the deviation of the household’s assets value from GDP in terms of the speed of expansion to assess the magnitude of recession or boom.

7 Concluding remark

This paper finds that there is a specific pattern in data which would be useful to detect an assets price bubble. The pattern is obtained by comparing the household’s asset value and nominal GDP and is observed commonly in the periods of Great Recession in U.S. and Land price bubble in Japan as well as Great Depression. Fig.1 to Fig.12 provide an evidences of that pattern. This result implies that severe economic contractions are often accompanied by assets price bubbles. Although it would be difficult to predict asset bubbles only by observing data about the household’s nominal GDP and nominal GDP, it is helpful to do that.

Then, the paper presents a dynamic stochastic general equilibrium model which features sentiment shocks to household’s expectation and the utility function into which household’s wealth enters directly. The latter feature is known as a formation of “spirit of capitalism”. Under this assumption, the sentiment shocks can generate co-movement of major macroeconomic variables such as GDP, consumption, investment and values of the assets. Thus, it is possible that asset price driven boom and burst cycles are caused by such sentiment shocks.

Actually, by estimating the model using U.S. data, it is found that the sentiment shocks account for mild but non-negligible part of the fluctuations of macroeconomic variables. For example, around 20% of the fluctuation of GDP, 10% of consumption, 19% of labor supply and 50% of residential investment are driven by the sentiment shocks altogether. Also, the analysis of the historical decomposition of the model suggests that the sentiment shocks characterize well a boom and bust cycle which is observed before and after the financial crisis in 2007. Since the sentiment shocks can play a role in accounting for the business cycles, future researches about the sentiment shocks would be fruitful. Although this paper focuses on the sentiment shocks in the household sector, it could be possible to assume sentiment shocks in the firm sector. Negative sentiment shocks in the firm sector may play a role in the decision of hiring in the labor market.

Finally, the conditional forecasts of the model show that a gap of household’s assets value and GDP growth may be a good measure to analyze a specific scenario such as the burst of asset price bubbles. This would be helpful to estimate how much damage hits the economy if the bubble bursts. More richly specified model can provide more accurate result.
References


Figure 1: Nominal GDP vs household total assets annual
Figure 2: Nominal GDP vs household financial assets annual
Figure 3: Nominal GDP vs household nonfinancial assets annual
Figure 4: Nominal Home price index vs household nonfinancial assets annual
Figure 5: Nominal GDP vs household’s net worth annual
Figure 6: Nominal GDP vs national net worth annual
Figure 7: Nominal GDP vs household total assets annual in Japan
Figure 8: Nominal GDP vs household financial assets annual in Japan
Figure 9: Nominal GDP vs household nonfinancial assets annual in Japan
Figure 10: Nominal GDP vs residential property prices for Euro area
Figure 11: Nominal GDP vs S & P index from 1891 to 1945
Figure 12: Nominal GDP vs home price index from 1891 to 1945
Figure 13: Impulse responses to an aggregate technology shock
Figure 14: Impulse responses to an investment-specific technology shock
Figure 15: Impulse responses to a housing-specific technology shock
Figure 16: Impulse responses to a labor supply shock
Figure 17: Impulse responses to a government spending shock
Figure 18: Impulse responses to a first sentiment shock
Figure 19: Impulse responses to a second sentiment shock
Figure 20: Impulse responses to a third sentiment shock
Figure 21: Impulse responses to a first sentiment shock. The solid line represents the benchmark case ($\omega_h = 0.19$). The dashed line represents the case of high $\omega_h$ ($\omega_h = 0.5$). The dotted line represents the case of low $\omega_h$ ($\omega_h = 0.0001$).
Figure 22: Impulse responses to a second sentiment shock. The solid line represents the benchmark case ($\omega_s = 14.9$). The dashed line represents the case of high $\omega_s$ ($\omega_s = 55.5$). The dotted line represents the case of low $\omega_s$ ($\omega_s = 1.1$).
Figure 23: Impulse responses to a technology shock. The solid line represents the benchmark case ($\omega_h = 0.19$). The dashed line represents the case of high $\omega_h$ ($\omega_h = 0.5$). The dotted line represents the case of low $\omega_h$ ($\omega_h = 0.0001$)
Figure 24: Historical decomposition of output growth.
Figure 25: The conditional and unconditional forecasts of GDP growth.

Figure 26: The conditional and unconditional forecasts of consumption.
Figure 27: The conditional and unconditional forecasts of business investment.

Figure 28: The conditional and unconditional forecasts of residential investment.
Figure 29: The conditional and unconditional forecasts of financial assets.

Figure 30: The conditional and unconditional forecasts of nonfinancial assets.
Table 1: Annual average growth rates (percent) and standard deviations of nominal GDP, household’s nonfinancial assets, financial assets and total assets

<table>
<thead>
<tr>
<th></th>
<th>Average growth rate (%)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal GDP</td>
<td>6.5</td>
<td>3.2</td>
</tr>
<tr>
<td>Nonfinancial assets</td>
<td>7.7</td>
<td>5.5</td>
</tr>
<tr>
<td>Financial assets</td>
<td>7.2</td>
<td>4.8</td>
</tr>
<tr>
<td>Total assets</td>
<td>7.3</td>
<td>4.2</td>
</tr>
<tr>
<td>Type</td>
<td>Prior Dist.</td>
<td>Prior Mean</td>
</tr>
<tr>
<td>------</td>
<td>-------------</td>
<td>------------</td>
</tr>
<tr>
<td>$\omega_c$</td>
<td>Preference for consumption</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\omega_h$</td>
<td>Preference for nonfinancial assets</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\eta$</td>
<td>Elasticity of substitution</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>Elasticity of intertemporal substitution</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\psi$</td>
<td>Frisch elasticity of labor supply</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\xi$</td>
<td>Input share in production</td>
<td>Beta</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>Input share in production</td>
<td>Beta</td>
</tr>
<tr>
<td>$\beta_e$</td>
<td>Discount factor of the firm</td>
<td>Beta</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Collateral constraint</td>
<td>Beta</td>
</tr>
<tr>
<td>$\phi_1$</td>
<td>Capital adj. cost</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\phi_h$</td>
<td>Adj. cost for nonfinancial assets</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\phi_e$</td>
<td>Adj. cost for nonfinancial assets</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\phi_q$</td>
<td>Adj. cost for nonfinancial assets</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\tau$</td>
<td>Capital utilization cost</td>
<td>Gamma</td>
</tr>
<tr>
<td>$\ln v$</td>
<td>Technology growth</td>
<td>Normal</td>
</tr>
<tr>
<td>$\ln lab$</td>
<td>Trend of labor supply</td>
<td>Normal</td>
</tr>
<tr>
<td>$q^a/Y^{dep}$</td>
<td>Price of financial asset in s.s.</td>
<td>Gamma</td>
</tr>
</tbody>
</table>

Table 2: Prior and posterior distribution of the parameters
<table>
<thead>
<tr>
<th>Type</th>
<th>Prior Distribution</th>
<th>Prior Mean</th>
<th>Prior S.D.</th>
<th>Posterior Mean</th>
<th>Posterior 5%</th>
<th>Posterior 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho_a$</td>
<td>Technology shock</td>
<td>Beta</td>
<td>0.5</td>
<td>0.15</td>
<td>0.93</td>
<td>0.90</td>
</tr>
<tr>
<td>$\rho_i$</td>
<td>Investment specific tech. shock</td>
<td>Beta</td>
<td>0.5</td>
<td>0.15</td>
<td>0.62</td>
<td>0.50</td>
</tr>
<tr>
<td>$\rho_h$</td>
<td>Housing specific tech shock</td>
<td>Beta</td>
<td>0.5</td>
<td>0.15</td>
<td>0.81</td>
<td>0.75</td>
</tr>
<tr>
<td>$\rho_l$</td>
<td>Labor supply shock</td>
<td>Beta</td>
<td>0.5</td>
<td>0.15</td>
<td>0.96</td>
<td>0.94</td>
</tr>
<tr>
<td>$\rho_g$</td>
<td>Government spending shock</td>
<td>Beta</td>
<td>0.5</td>
<td>0.15</td>
<td>0.94</td>
<td>0.91</td>
</tr>
<tr>
<td>$\rho_q$</td>
<td>First sentiment shock</td>
<td>Beta</td>
<td>0.5</td>
<td>0.15</td>
<td>0.97</td>
<td>0.95</td>
</tr>
<tr>
<td>$\rho_s$</td>
<td>Second sentiment shock</td>
<td>Beta</td>
<td>0.5</td>
<td>0.15</td>
<td>0.97</td>
<td>0.96</td>
</tr>
<tr>
<td>$\rho_b$</td>
<td>Third sentiment shock</td>
<td>Beta</td>
<td>0.5</td>
<td>0.15</td>
<td>0.95</td>
<td>0.93</td>
</tr>
<tr>
<td>$\sigma_a$</td>
<td>Technology shock</td>
<td>Inv. gamma</td>
<td>0.1</td>
<td>2</td>
<td>0.24</td>
<td>0.21</td>
</tr>
<tr>
<td>$\sigma_i$</td>
<td>Investment specific tech. shock</td>
<td>Inv. gamma</td>
<td>0.1</td>
<td>2</td>
<td>1.68</td>
<td>0.70</td>
</tr>
<tr>
<td>$\sigma_h$</td>
<td>Housing specific tech shock</td>
<td>Inv. gamma</td>
<td>0.1</td>
<td>2</td>
<td>3.14</td>
<td>1.84</td>
</tr>
<tr>
<td>$\sigma_l$</td>
<td>Labor supply shock</td>
<td>Inv. gamma</td>
<td>0.1</td>
<td>2</td>
<td>0.50</td>
<td>0.39</td>
</tr>
<tr>
<td>$\sigma_g$</td>
<td>Government spending shock</td>
<td>Inv. gamma</td>
<td>0.1</td>
<td>2</td>
<td>1.20</td>
<td>1.09</td>
</tr>
<tr>
<td>$\sigma_q$</td>
<td>First sentimental shock</td>
<td>Inv. gamma</td>
<td>0.1</td>
<td>2</td>
<td>0.23</td>
<td>0.17</td>
</tr>
<tr>
<td>$\sigma_s$</td>
<td>Second sentimental shock</td>
<td>Inv. gamma</td>
<td>0.1</td>
<td>2</td>
<td>0.06</td>
<td>0.04</td>
</tr>
<tr>
<td>$\sigma_b$</td>
<td>Third sentimental shock</td>
<td>Inv. gamma</td>
<td>0.1</td>
<td>2</td>
<td>0.22</td>
<td>0.16</td>
</tr>
</tbody>
</table>
Table 4: Business cycle properties

<table>
<thead>
<tr>
<th>Variance (percent)</th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \ln Y^{GDP} )</td>
<td>0.08</td>
<td>0.11</td>
</tr>
<tr>
<td>( \Delta \ln C )</td>
<td>0.12</td>
<td>0.07</td>
</tr>
<tr>
<td>( \Delta \ln I )</td>
<td>0.69</td>
<td>0.79</td>
</tr>
<tr>
<td>( \Delta \ln I^h )</td>
<td>3.54</td>
<td>4.01</td>
</tr>
<tr>
<td>( \Delta \ln F )</td>
<td>1.01</td>
<td>0.89</td>
</tr>
<tr>
<td>( \Delta \ln Z )</td>
<td>0.53</td>
<td>0.32</td>
</tr>
<tr>
<td>( \Delta \ln q )</td>
<td>0.57</td>
<td>0.25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Autocorrelation (first order)</th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \ln Y^{GDP} )</td>
<td>0.04</td>
<td>0.31</td>
</tr>
<tr>
<td>( \Delta \ln C )</td>
<td>-0.01</td>
<td>0.31</td>
</tr>
<tr>
<td>( \Delta \ln I )</td>
<td>0.59</td>
<td>0.57</td>
</tr>
<tr>
<td>( \Delta \ln I^h )</td>
<td>0.62</td>
<td>0.59</td>
</tr>
<tr>
<td>( \Delta \ln F )</td>
<td>0.00</td>
<td>0.12</td>
</tr>
<tr>
<td>( \Delta \ln Z )</td>
<td>0.09</td>
<td>0.81</td>
</tr>
<tr>
<td>( \Delta \ln q )</td>
<td>0.08</td>
<td>0.58</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Model</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \Delta \ln C, \Delta \ln Y^{GDP} )</td>
<td>0.57</td>
<td>0.66</td>
</tr>
<tr>
<td>( \Delta \ln I, \Delta \ln Y^{GDP} )</td>
<td>0.29</td>
<td>0.54</td>
</tr>
<tr>
<td>( \Delta \ln I^h, \Delta \ln Y^{GDP} )</td>
<td>0.26</td>
<td>0.58</td>
</tr>
<tr>
<td>( \Delta \ln F, \Delta \ln Y^{GDP} )</td>
<td>0.26</td>
<td>0.21</td>
</tr>
<tr>
<td>( \Delta \ln Z, \Delta \ln Y^{GDP} )</td>
<td>0.33</td>
<td>0.31</td>
</tr>
<tr>
<td>( \Delta \ln q, \Delta \ln Y^{GDP} )</td>
<td>0.26</td>
<td>0.21</td>
</tr>
</tbody>
</table>
### Table 5: Asymptotic forecast error variance decomposition

<table>
<thead>
<tr>
<th></th>
<th>GDP</th>
<th>Consumption</th>
<th>Labor</th>
<th>Business investment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate tech</td>
<td>18.4</td>
<td>25.0</td>
<td>2.9</td>
<td>4.4</td>
</tr>
<tr>
<td>Investment-specific tech</td>
<td>2.6</td>
<td>1.8</td>
<td>2.3</td>
<td>71.6</td>
</tr>
<tr>
<td>Housing-specific tech</td>
<td>3.7</td>
<td>3.6</td>
<td>4.6</td>
<td>0.5</td>
</tr>
<tr>
<td>Labor supply</td>
<td>37.3</td>
<td>50.6</td>
<td>46.9</td>
<td>11.8</td>
</tr>
<tr>
<td>Government spending</td>
<td>15.5</td>
<td>4.2</td>
<td>21.2</td>
<td>3.8</td>
</tr>
<tr>
<td>First sentiment</td>
<td>13.9</td>
<td>10.5</td>
<td>17.9</td>
<td>4.5</td>
</tr>
<tr>
<td>Second sentiment</td>
<td>0.3</td>
<td>1.0</td>
<td>0.7</td>
<td>0.0</td>
</tr>
<tr>
<td>Third sentiment</td>
<td>8.0</td>
<td>3.0</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Residential investment</th>
<th>Financial assets</th>
<th>Nonfinancial assets</th>
<th>Housing price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate tech</td>
<td>1.4</td>
<td>2.2</td>
<td>2.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Investment-specific tech</td>
<td>0.1</td>
<td>0.3</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Housing-specific tech</td>
<td>44.8</td>
<td>1.3</td>
<td>2.8</td>
<td>78.7</td>
</tr>
<tr>
<td>Labor supply</td>
<td>2.0</td>
<td>4.3</td>
<td>3.7</td>
<td>0.9</td>
</tr>
<tr>
<td>Government spending</td>
<td>0.0</td>
<td>0.1</td>
<td>0.4</td>
<td>0.0</td>
</tr>
<tr>
<td>First sentiment</td>
<td>12.3</td>
<td>0.3</td>
<td>88.7</td>
<td>4.3</td>
</tr>
<tr>
<td>Second sentiment</td>
<td>0.4</td>
<td>85.0</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Third sentiment</td>
<td>38.6</td>
<td>6.2</td>
<td>2.1</td>
<td>14.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>stock price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aggregate tech</td>
<td>1.8</td>
</tr>
<tr>
<td>Investment-specific tech</td>
<td>0.3</td>
</tr>
<tr>
<td>Housing-specific tech</td>
<td>0.1</td>
</tr>
<tr>
<td>Labor supply</td>
<td>3.3</td>
</tr>
<tr>
<td>Government spending</td>
<td>0.2</td>
</tr>
<tr>
<td>First sentiment</td>
<td>0.1</td>
</tr>
<tr>
<td>Second sentiment</td>
<td>93.5</td>
</tr>
<tr>
<td>Third sentiment</td>
<td>0.3</td>
</tr>
</tbody>
</table>
Appendix A  Data description and measurement equations

The model is estimated using U.S. quarterly data. Data consist of real GDP (\( Y_{t,\text{gdp,\text{data}}} \)), consumption (\( C_{t,\text{data}} \)), business fixed investment (\( I_{t,\text{data}} \)), residential investment (\( I_{t,\text{h,\text{data}}} \)), hours worked (\( N_{t,\text{data}} \)), households’ nonfinancial assets (\( Z_{t,\text{data}} \)), households’ financial assets (\( F_{t,\text{data}} \)), house price index (\( q_{t,\text{h,\text{data}}} \)). These series are defined as follows:

\[
Y_{t,\text{gdp,\text{data}}} = \frac{GDPC1}{CNP160V} \\
C_{t,\text{data}} = \frac{PCECC96}{CNP160V} \\
I_{t,\text{data}} = \frac{PNFI}{GDPDEF * CNP160V} \\
I_{t,\text{h,\text{data}}} = \frac{FPNI}{GDPDEF * CNP160V} \\
N_{t,\text{data}} = \frac{PRS85006023 * CE160V}{CNP160V} \\
Z_{t,\text{data}} = \frac{TTABSHNO}{CNP160V * GDPDEF} \\
F_{t,\text{data}} = \frac{TFAABSHNO}{CNP160V * GDPDEF} \\
q_{t,\text{h,\text{data}}} = \frac{USSTHP1NBD20090401}{GDPDEF}
\]

The original data and their sources are described below.

**GDPC1:** Real Gross Domestic Product, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate. Source: US. Bureau of Economic Analysis


**PCECC96:** Real Personal Consumption Expenditures, Billions of Chained 2009 Dollars, Quarterly, Seasonally Adjusted Annual Rate. Source: US. Bureau of Economic Analysis

**PNFI:** Private Nonresidential Fixed Investment, Billions of Dollars, Quarterly, Seasonally Adjusted Annual Rate Source: US. Bureau of Economic Analysis

**PRFI:** Private Residential Fixed Investment, Billions of Dollars, Quarterly, Seasonally Adjusted Annual Rate Source: US. Bureau of Economic Analysis

**GDPDEF:** Gross Domestic Product: Implicit Price Deflator, Index 2009=100, Quarterly, Seasonally Adjusted. Source: US. Bureau of Economic Analysis

**PRS85006023:** Nonfarm Business Sector: Average Weekly Hours, Index 2009=100, Quarterly, Seasonally Adjusted

**CE160V:** Civilian Employment, Thousands of Persons, Quarterly, Seasonally Adjusted

**TTABSHNO:** Households and Nonprofit Organizations; Nonfinancial Assets, Level, Billions of Dollars, Quarterly, Not Seasonally Adjusted

52
TFAABSHNO: Households and Nonprofit Organizations; Total Financial Assets, Level, Billions of Dollars, Quarterly, Not Seasonally Adjusted

USSTHPI: All-Transactions House Price Index for the United States, Index Q2 2009=100, Quarterly, Not Seasonally Adjusted

Measurement equations are represented as follows:

\[ 100 \times \Delta \ln Y_{t}^{\text{data}} = \hat{Y}_{t}^{gdp} - \hat{Y}_{t-1}^{gdp} + \ln v \]
\[ 100 \times \Delta \ln C_{t}^{\text{data}} = \hat{C}_{t} - \hat{C}_{t-1} + \ln v \]
\[ 100 \times \Delta \ln I_{t}^{\text{data}} = \hat{I}_{t} - \hat{I}_{t-1} + \ln v \]
\[ 100 \times \Delta \ln I_{t}^{h,\text{data}} = \hat{I}_{t}^{h} - \hat{I}_{t-1}^{h} + \ln v \]
\[ 100 \times \ln N_{t} = \hat{N}_{t} + \ln j \]
\[ 100 \times \Delta \ln Z_{t}^{\text{data}} = \hat{Z}_{t} - \hat{Z}_{t-1} + \ln v \]
\[ 100 \times \Delta \ln F_{t}^{\text{data}} = \hat{F}_{t} - \hat{F}_{t-1} + \ln v \]
\[ 100 \times \Delta \ln q_{t}^{h,\text{data}} = \hat{q}_{t}^{h} - \hat{q}_{t-1}^{h} + \ln v \]

where a variable with a hat denotes the percent deviation from its steady-state value.