Why The Housing Sector Leads The Whole Economy: the Importance of Collateral Constraints and News Shocks☆

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Abstract

This paper establishes a dynamic stochastic partial equilibrium model for explaining residential investment dynamics in the United States, focusing on the distinctive cyclical features of residential investment in that it leads the whole economy. This paper is different from the existing literature by adding three new features to the model: news shocks, collateral constraints and agent heterogeneity. The partial equilibrium analysis where interest rates are exogenously fixed shows that these assumptions are essential to generating the dynamic pattern in which residential investment leads consumption and GDP.

JEL classification: E21; E25; E32

Keywords: News shocks, Heterogeneous agents, Housing sector, Collateral constraints, Aggregate uncertainty

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1. Introduction

For a long time, the housing sector has led the entire economy in the business cycles of the United States (see, for examples, Green, 1997; Greenwood and Hercowitz, 1991 and Leamer, 2007 etc.). Why does the housing sector lead the whole economy? What does its leadership reveal about the structure of the economy and consumer behavior? This paper proposes a theoretical model to reflect the way that residential investment leads consumption and GDP.

Housing is an important sector in business cycles. It contributes around 50 percent of the aggregate wealth per household, according to Greenwood and Hercowitz (1991) and Bertaut and Starr (2000). The variations in house values generate large wealth effects on consumer choices regarding consumption and investment. For example, Case et al. (2005) indicate that house prices have a statistically significant and rather large positive effect on household consumption. Using micro data, Campbell and Cocco (2007) confirm the significant response of household consumption to house prices. Similarly, Black et al. (1996) indicate that a 10 percent increase in house prices leads to a 5 percent increase in the number of small firms in England because of the relaxed financial constraints introduced by the rise of collateral values (house prices). Moreover, residential investment is a good predictor of economic recession. In the past fifty years, eight of ten recessions (including the most recent one) were preceded by a severe reduction in residential investment, as reported by Leamer (2007). Therefore, if we hope to explain and quantify business cycles, we cannot ignore the role played by the housing sector. Leamer (2007) stresses that the housing sector is very important to economic recessions, and any attempt to understand business cycle needs to focus on housing investments in particular.[1]

One must take two steps to fully understand the effects of the housing sector on the economy. The first step is to study how consumers choose between consumption and

[1] In Leamer (2007), household investment includes residential investment and consumer durables. The data from National Income and Product Accounts(NIPA) shows that residential investment not only leads gross domestic product more but also has higher volatility than consumer durables.

house purchases during business cycles. The second is to explore how the changes in house prices generated by consumer choices will affect current investment and, hence, future output through the credit market. Our paper contributes to this research area by focusing on the first step only. We study the quantity changes, rather than price changes, in the housing sector. This strategy not only simplifies our analytical framework, but also helps clearly display the mechanism through which consumers adjust their demand for houses.

The quantity changes in the housing sector (i.e., residential investment) lead GDP, whereas consumption coincides with GDP. Figure 1 plots detrended data for consumption, residential investment and GDP. Clearly, residential investment is about one or two quarters ahead of consumption and GDP. Consumption coincides with GDP. Green (1997) uses the Granger-causality test to determine that residential investment leads consumption and GDP significantly, whereas neither consumption nor GDP leads residential investment. The purpose of our paper is to quantitatively explain this trend. Our mechanisms and quantitative analysis help us to understand how consumers make choices between consumption and house purchases in business cycles. We consider it essential to explore the roles played by the housing sector in business cycles before moving forward.

[Figure 1 around here]

In this paper, three key assumptions help to explain the dynamics of residential investment. First, collateralized consumer loans, such as mortgages, are less restricted in size and carry lower interest rates than do unsecured consumer loans, such as credit card debt. This assumption is consistent with the data for the U.S. financial market. In 2002, the 30-year mortgage interest rate in the U.S. was 6.40%, while the average interest rate for credit card debt was 16.6%.[2] This suggests that, even if unsecured consumer loans are available to everyone, the high cost of borrowing will keep most consumers from using

[2] The data on the mortgage rate is taken from International Monetary Fund (2002). The data on the credit card rate is taken from Gross and Souleles (2002).

them as a major financing source. In 2001, 81.5% of consumer loans were collateralized by residential properties, whereas unsecured consumer loans amounted to only 10%. [3]

Second, we assume that the agents receive noisy news about future income or total factor productivity (TFP). The news shocks change expectations about the future and hence affect the consumption and investment choices of consumers. This idea was proposed in the early literature by researchers such as Pigou (1927), and has begun to recently attract more attention. People find that contemporaneous shocks to technologies, money, oil prices and credit can account for only a small part of the variation in output (Cochrane, 1994; Beaudry and Lucke, 2009). Beaudry and Portier (2006) provide the empirical evidence that equity prices reflect the news shocks of TFP and predict TFP growth in the long term. This gives support to the idea of news shocks as an important resource for business cycles. The following literature takes the ideas of Beaudry and Portier (2006) and all regards stock prices as the mirrors of the future (Beaudry and Portier, 2004; Beaudry and Portier, 2007; Jaimovich and Rebelo, 2009; Schmitt-Grohe and Uribe, 2008 and Khan and Tsoukalas, 2009 etc.). Our paper contributes to this body of literature by applying this assumption to the model of heterogeneous agents and housing sectors. Then, news shocks are not only reflected in the stock prices but also the consumption and the residential investment.

Through numerical experiments, we find that collateral constraints and news shocks are both essential to generating the leadership of the housing sector over business cycles. Once they have been hit by the news shocks, the agents change their expectations about their future income and hence think differently about current house purchases and consumption. Financial constraints then restrain agent choices because the news shocks about income changes take some time to become reality, and, in the meantime, current incomes remain the same. During this process, wealth heterogeneity plays an important role in the

[3] The education loans constitute about 50 percent of the unsecured loans. These statistics are taken from Aizcorbe et al. (2003) computing these numbers with the data of Survey of Consumer Finance (SCF, 2001).

mechanism through which the collateral constraints amplify the response of house purchases to news shocks. Consumers at heterogeneous wealth levels adopt different policies in response to the news shocks: the degree to which they adjust both consumption and housing purchases decreases with wealth levels. In particular, agents with a low wealth level adjust their housing purchases more than their consumption because of collateral constraints. Hence, the collateral constraints and the news shocks interact with the agent heterogeneity in generating the housing sector's leadership of the economy. Through this mechanism, news shocks can generate much deeper effects on aggregate volatility when combined with financial constraints than without them. This point is not given sufficient attention in the current literature on news shocks. Moreover, wealth heterogeneity also affects the business cycles containing news shocks even when all agents have the same information about the future, and this consideration has not been studied yet.

Our paper also contributes to the large body of literature about economies composed of heterogeneous agents that involve aggregate uncertainty. Some studies focus on the interaction between the collateral constraints, the housing sectors and aggregate dynamics. For example, Iacoviello (2005) sets up a monetary business cycle model with heterogeneous agents, savers (patient workers) and borrowers (impatient entrepreneurs), with collateral constraints tied to house values. Hercowitz and Campbell (2005) use a similar borrower-saver model and find that the reduced collateral constraints can explain the decline in aggregate volatility since the 1980s. In terms of the technical details of our model, our study is more similar to the work of Cocco (2005), Yao and Zhang (2005), Li and Yao (2007), Silos (2007), Kiyotaki et al. (2007) and Fisher and Gervais (2007). These authors develop and quantify the heterogenous-agent model of consumption and house purchases under the assumptions of aggregate income shocks or varying house prices. Our paper contributes to this literature by providing an analysis of the effects of the news shocks on the agents' behavior, expanding the available financial tools from mortgages alone to both mortgages and credit cards, and quantitatively showing that residential investment leads the economy.

Our paper is also related to the body of literature that studies neoclassical growth models for housing sectors. These studies seek to match the co-movements between consumption, business investment, residential investment and output. They include the papers by Greenwood and Hercowitz (1991), Benhabib et al. (1991), Gomme et al. (2001), Davis and Heathcote (2005), Fisher (2007) and Gomme and Rupert (2007). The common features of these papers are that they propose dynamic stochastic general equilibrium models of homogeneous agents and that they consider contemporaneous shocks. Fisher (2007) successfully obtains the result that residential investment leads business investment by assuming that the increase of housing stocks help to improve the labor productivity. However, the leadership of house sector over the whole economy is still missing in his paper while our paper will focus on this leadership relation. Gomme and Rupert (2007) are the most recent contributors to this body of literature and proposes carefully calibrated two-sector models. They find that the stochastic growth models of contemporaneous shocks fail to indicate the leadership of residential investment over GDP and consumption.

The structure of the paper is as follows. In section 2, we provide the detailed setup of the model and define the equilibrium. In section 3, we calibrate and parameterize the model. Section 4 displays the numerical results from the experiments and compare different models in order to highlight the importance of the key assumptions made in our model. Section 5 concludes this paper, and discusses some directions of future research.

2. Model

2.1. Agents

The economy consists of a continuum of infinitely-lived agents maximizing their expected lifetime utility. For any agent $j \in [0,1]$, the objective function is defined by

$$E_0 \left[\sum_{t=0}^{\infty} \beta^t U(c_t^j, h_t^j) \right],$$

where $\beta \in [0,1)$ is the discount factor, $c_t^j \geq 0$ is the consumption and $h_t^j \geq 0$ is the self-owned house. The period utility satisfies the following CES form [4]

$$U(c,h) = (1-\kappa_h)\ln c + \kappa_h \ln h. \tag{1}$$

At each period, the agent receives an endowment which consists of idiosyncratic income and aggregate income. For the agent $j \in [0,1]$, the budget constraint is defined by

$$c_t^j + h_{t+1}^j + a_{t+1}^j \leq a_t^j + h_t^j(1-\delta_h) + \epsilon_t^j z_t + \chi(h_{t+1}^j, h_t^j) + \mathcal{I}(a_t^j, h_t^j), \tag{2}$$

where a_t^j is the financial asset, h_t^j is the house, δ_h is the depreciation rate of the house, ϵ_t^j is the idiosyncratic income, z_t is the aggregate income shock and $\mathcal{I}$ denotes capital income. The function χ defines the costs of house adjustment. We assume that by adjusting the quantity of housing, the agents have to pay ϕ percent of the values of their old houses as the adjustment costs. Hence χ satisfies

$$\chi(h_{t+1}^j, h_t^j) = \begin{cases} -\phi h_t^j & \text{if } h_{t+1}^j \neq h_t^j \\ 0 & \text{if } h_{t+1}^j = h_t^j. \end{cases}$$

The aggregate productivity shock z_t and the idiosyncratic income shock ϵ_t^j are two Markov processes independent of each other. We assume that Ω is the set of idiosyncratic

[4] It is the service flow of the housing capital that contributes to personal utility. However, given the two assumptions of Cob-Douglas home production and CES utility function, we can transform the utility function into the form specified in utility function. For example, suppose that the utility function satisfies

$$\mathcal{U}(c, c_h) = (1-\kappa_h')\ln c + \kappa_h' \ln c_h,$$

where c_h is the service flow from the housing capital. Assume that the household production function satisfies Cob-Douglas form:$c_h = h^{\alpha_h}$. Then by putting this home production function back into the above equation, we can obtain the CES utility function specified by Equation (1).

income states. The transition matrix is denoted as $P^\epsilon = [p^\epsilon_{mn}]$ with

$$p^\epsilon_{mn} = \text{Prob}(\epsilon' = \epsilon^m | \epsilon = \epsilon^n).$$

$\mathcal{Z}$ is the set of aggregate income states, and the transition matrix is $P^z = [p^z_{mn}]$ with

$$p^z_{mn} = \text{Prob}(z' = z^m | z = z^n).$$

2.2. Market Arrangement

There are two forms of consumer debts available in the financial market. The first form of consumer debt is mortgage, of which the interest rate is denoted by r. But the mortgages need to be collateralized by the house values. We use γ to denote the percentage of the house values agents can use as the collateral. It implies that the agents can only borrow up to $\gamma \in [0, 1)$ percent of their house values through the mortgages. The second form is credit card debt, for which the agents need to pay a very high interest rate $r^c \gg r$. We denote h as the value of the houses. Then, the debts smaller than γh are charged with the interest rate r and the debts exceeding γh are charged with credit card rates. The interest rates r and r^c are exogenously given and fixed over time.

Given the above arrangements of financial markets, the capital return $\mathcal{I}$ in the budget constraint is given by

$$\mathcal{I}(a^j_t, h^j_{t-1}) = \begin{cases} r a^j_t & \text{if } a^j_t \geq -\gamma h^j_{t-1} \\ -r\gamma h^j_{t-1} + (a^j_t + \gamma h^j_{t-1}) r^c & \text{if } a^j_t < -\gamma h^j_{t-1}. \end{cases}$$

If the consumer does not borrow more than γh^j_{t-1}, he/she pays or receives the interest rates r. If the consumer borrows more than the value of collateral γh^j_{t-1}, he/she has to pay for two levels of interest rate costs. For the part of secured consumer debts (or financial assets) $-\gamma h_{t-1}$, the agent pays (or receives) a low interest rate r. For the part of unsecured loans $a^j_t + \gamma h^j_{t-1}$, the agent pays a high interest rate r^c. We assume that the interest rates r and r^c are fixed over time and make the quantitative analysis under the framework of partial equilibrium. This set up reduces the costs of computation a lot without hurting the fulfillment of the purpose of our paper.

2.3. News Structure

We denote z_t as the current productivity/aggregate income shocks, z_{t+1} as the future productivity/aggregate income shocks and s_t as the current signal. At period t, the agents receive the signal s_t which contains the information about z_{t+1}. z_t, z_{t+1} and s_t satisfy the following conditions

$$z_{t+1} = \rho z_t + \nu_{t+1}$$
$$s_t = \rho z_t + \eta_t.$$

The disturbances (ν_{t+1}, η_t) are i.i.d processes and satisfy the following conditions:

$$(\nu_{t+1}, \eta_t) \perp z_t$$
$$(\nu_{t+1}, \eta_t) \sim N(0, \Pi),$$

where Π is defined by

$$\Pi = \sigma_\nu^2 \begin{bmatrix} 1 & \pi \\ \pi & 1 \end{bmatrix}.$$

σ_ν denotes the standard deviation of the disturbances. π denotes the correlation coefficient of η_t and ν_{t+1}. π describes the accuracy of the signal. If $\pi = 1$, the disturbance η_t of the signal is highly correlated with the disturbance ν_{t+1} of the future productivity. The signal contains full information about the future productivity. If $\pi = 0$, η_t is uncorrelated with ν_{t+1}. The signal contains no more information than the current productivity does.

Therefore, the higher π is, the more information the signal contains about the future productivity.

We make this assumption about the news structure for the following two reasons. Firstly, although a large literature displays and stresses the forecasting powers of several kinds of signals, it is still far from reaching the agreement on which one should be the best one. Therefore, we do not have any empirical literature estimating the parameter about the accuracy of the news. Secondly, the purpose of our paper is to show the mechanism through which the news affects the choices of the consumers. Hence, this setup is easy for us to display and compare the numerical results of different levels of π.

In order to make the computation feasible, we need to discretize the states of the above two stochastic processes. We do so by extending the method proposed by Tauchen (1986) from one dimension to two dimensions. Appendix B describes in details the method of discretization used in this paper. After discretization, we denote $\mathcal{Z}$ as the set of aggregate income shocks. The set of signal states is denoted by $\mathcal{S}$ and satisfies $\mathcal{S} = \mathcal{Z}$. We denote the transition matrix between (z, s) to (z', s') as Θ.

2.4. Definition of Recursive Partial Equilibrium

Given interest rates (r, r^c), the recursive partial equilibrium is composed of state space, value function, policy functions, and distribution function. The state space is as encompassing housing capital $h \in \mathcal{H}$, the wealth $w \in \mathcal{W}$, the present idiosyncratic income shock ϵ, the aggregate income shock z, and the signal s for z'.

The value function $\mathcal{V}$, the policy functions of housing asset g_h and financial asset g_w

satisfy the following equations

$$\mathcal{V}(h, w, \epsilon, z, s) = \max_{\{c,h',w'\}} \{U(c, h') + \beta E\mathcal{V}(h', w', \epsilon', z', s'|\epsilon, z, s)\}$$

subject to:

$$c + h' + a' \leq \epsilon z + w(1 + r) + \chi(h', h)$$

$$w' = \begin{cases} a' + h'\frac{1-\delta_h}{1+r} & \text{if } a' \geq -\gamma h' \\ (a' + \gamma h')\frac{1+r^c}{1+r} - \gamma h' + h'\frac{1-\delta_h}{1+r} & \text{if } a' < -\gamma h' \end{cases} \tag{3}$$

$$w'r \geq -\underline{\epsilon z}. \tag{4}$$

Equation (3) defines the wealth of the next period w'. Equation (4) guarantees that the agents can pay the interest rates of their debts even if they have the lowest income in the next period. $\underline{\epsilon}$ is the lowest value in the set of idiosyncratic income shocks. $\underline{z}$ is the lowest value in the set of aggregate income shocks. This means that the agents cannot borrow more than the amount that their lowest possible wage income can support, based on the cost of the interest rates associated with the consumer loans. A large literature has applied the similar assumption in the models of the heterogeneous agent, for example Aiyagari (1994). The choice variables are the consumption c, the current house h', and the future financial asset a'. Therefore, the policy functions can be denoted as the following: the current consumption $c = g_c(h, w, \epsilon, z, s)$; the current house $h' = g_h(h, w, \epsilon, z, s)$; and the future wealth $w' = g_w(h, w, \epsilon, z, s)$.

λ denotes the distribution of all agents over the state variables (h, w, ϵ), which is updated each period. Given the states of the next period (h', w', ϵ'), if the set $\mathcal{B}$ is defined as

$$\mathcal{B} = \{(h, w, \epsilon) \in \mathcal{H} \times \mathcal{W} \times \Omega | h' = g_h(h, w, \epsilon, z, s), w' = g_w(h, w, \epsilon, z, s)\},$$

the updated distribution function satisfies

$$\lambda'(h', w', \epsilon') = \int_{\mathcal{B}} \lambda(h, w, \epsilon) p^{\epsilon}(\epsilon'|\epsilon) dh dw d\epsilon.$$

3. Calibration and Parametrization

In this model, the set of parameters includes preferences $\{\beta, \kappa_h\}$, market $\{r, r_h, \delta_h, \gamma, \phi\}$, and productivity $\{\Omega, p^{\epsilon}, \rho, \sigma_{\nu}, \pi\}$. Table 1 displays the parameters used in the simulations. We will explain how to determine the values of these parameters in this section. Appendix A describes all the data used in this paper.

We choose the weight of housing in the utility function κ_h such that the ratio of residential investment over personal domestic consumption is 0.079, which is the mean of the ratio of residential investment to personal consumption expenditure (1959-2008). The after-tax yearly mortgage rate is chosen to be 5.7%. Under the U.S. tax system, mortgage payments can be taken as income tax deductions. With the capital tax rate set at 29.2%, this means that the mortgage rate before tax is 8.0%, which is the average of real 30-year conventional fixed mortgage rates from 1971:II to 2009:I.[5] The credit card rate is taken from Gross and Souleles (2002). The depreciation rate of the houses δ_h is chosen to be 0.013 which is the mean of the ratios of residential investment to the aggregate value of houses (1959-2008). γ is calibrated such that the ratio of aggregate owner-occupied house value over GDP is consistent with the mean of the data (1959-2008), which is 5.8. Because ϕ measures the adjustment costs of houses, its value affects how often and how large the agents change their houses. Hence, we calibrate ϕ to match the volatility of the residential investment.

We take the parameters of the idiosyncratic income process from the paper by Cagetti and Nardi (2006). They assume that the income process is AR(1) and approximate it with a five-point discrete Markov chain. The autocorrelation coefficient of the earning

[5]The value of the capital tax rate is taken from Gomme and Rupert (2007).

process is 0.95 and the variance is chosen to match the Gini coefficient of earnings of 0.38. Please refer to Appendix C for the parameters of the idiosyncratic income shocks. The aggregate income process z follows the process for the HP filtered real GDP from NIPA (1947:I to 2008:I). For the parameter describing the precision of news shocks π, we compute and compare two different values of π, 0.2 and 0.8, in the Section 4 of numerical simulations.

[Table 1 around here]

4. Numerical Results

We compute and compare three economies. In the benchmark economy, the agents can access to mortgages and credit cards. They also receive news about next-period productivity with the correlation between the two disturbances, π, equal to 0.8. In Economy I, the agents face the same financial market structures. However, we set $\pi = 0.2$, which means that the news is less informative in this economy than in the benchmark economy. In Economy II, $\gamma = 0$ and $\pi = 0.8$. This implies that the agents cannot access any mortgages although they can receive information as much as in the benchmark economy. In all these economies, we treat GDP as given exogenously and simulate consumption and residential investment. Figures 2, 3 and 4 plot the simulated data. They provide a direct way to compare the lead-lag relationship of the three variables in different models. Table 2 displays the moments of the data simulated by these three economies, particularly the correlation coefficients between GDP and the variables in different periods. We try to reveal the lead and lag patterns from these correlation coefficients.

By comparing Figure 1 and Figure 2, we can find that residential investment leads consumption and GDP in the benchmark economy like what the data display. This can also be shown by Table 2. Both in the data and in the benchmark economy, GDP has the largest correlation coefficient with current consumption among the consumptions in all periods. This is consistent with the fact that GDP coincides with consumption. In addition, GDP has the largest correlation coefficient with one-period-lagged residential investment. This shows that residential investment leads GDP. However, this leadership disappears in Economy I and Economy II since GDP has the largest correlation coefficient with current residential investment in these two economies. We can also look at Figure 3 and Figure 4 which display that residential investment comove with consumption and GDP in both Economy I and Economy II. These simulation results suggest that both news shocks and mortgage are necessary to generate the leadership of residential investment over the whole economy.

[Figure 2 around here]

[Figure 3 around here]

[Figure 4 around here]

[Table 2 around here]

A simple example can be used to illustrate the main mechanism at work in this paper. An agent receives good news about future productivity shocks and wants to increase current purchases, including housing purchases, to intertemporally smooth his/her consumption. Because his/her current income does not increase, he/she must use his/her savings to finance the increased expenditures. He/she is able to borrow at a low rate of interest for most housing purchases, and this is not possible for purchases of other types of consumption. As a result, the agent will spend more on housing than on other goods. In other words, the accessibility of credit through mortgages makes residential investment respond more quickly to the signals of future TFP shocks. This explains why residential investment leads consumption and GDP. If the signal turns out to be accurate, the agent will achieve a higher income and become less financially constrained than he/she is today. At this time, he/she will be able to increase his/her consumption of other goods, which explains why consumption tends to coincide with GDP.

In Economy I, which lacks news about the future TFP, the agents can only adjust consumption and residential investment simultaneously after observing the current aggregate shocks. Hence, we can observe that both consumption and the residential investment coincide with GDP. In Economy II, although the agents receive signals about future productivity, their financial constraints keep them from quickly responding to information shocks. Those who are experiencing financial constraints must wait to make adjustments until the next period, when they will have the higher income realized. Therefore, residential investment shares certain cyclical features with consumption. The highest correlation coefficients in both cases are with current GDP. It is interesting to compare this result with the one that we achieve in analyzing Economy I. In this economy, the lack of access to mortgages makes residential investment behave like consumption in its dynamic features; i.e., it acts as though agents do not receive any informative news.

Comparison of the numerical results of the three models leads us to conclude that only the benchmark economy indicates that residential investment leads consumption and GDP. This suggests that the two assumptions of news shocks and collateral constraints are crucial in generating the cyclical features of residential investment consistent with the U.S. data.

5. Conclusion

This paper establishes a dynamic stochastic partial equilibrium model that can be used to explain residential investment dynamics in the United States, focusing on the distinctive cyclical features of residential investment that it leads the entire economy. This paper departs from the existing literature in adding three new features to the model that help to generate the dynamics of residential investment in accordance with the data. These three distinctive assumptions are news shocks, collateral constraints and agent heterogeneity. The partial equilibrium analysis in which interest rates are exogenously fixed shows that the assumptions of news shocks and collateral constraints are essential to the generation of the conditions under which residential investment leads consumption and GDP. The key mechanism for these results is that in response to good information, agents purchase houses more than other goods because they are bound by collateral constraints.

We can definitely achieve more significant results by expanding this model from a partial equilibrium model to a general equilibrium model. By introducing the production sector into the model, we could explore how the economy shapes residential investment and business investment over time. In particular, business investment has a special feature in that it lags behind the whole economy. What does this fact reveal about agent choices regarding consumption, residential investment and business investment? Furthermore, how does this choice affect aggregate dynamics of the economy such like volatility and even social welfare? These questions should be addressed by future research.

Appendix

A. Data

This section describes all the data used in this paper.

1. Gross domestic product, BEA, NIPA table 1.1.5, line 1
2. Personal consumption expenditures, BEA, NIPA table 1.1.5, line2
3. Gross private domestic investment, BEA, NIPA table 1.1.5, line 7
4. Government consumption expenditure and gross investment, BEA, NIPA table 1.1.5, line 21
5. Residential investment, BEA, NIPA table 1.1.5, line 21, line 12
6. Imputed rentals of self-owned houses, BEA, NIPA table 2.5.5, line 21
7. Consumer price index, BEA, NIPA table 1.1.4, line 2
8. Aggregate house values, BEA, NIPA table 2.1, line 60
9. Mortgage rates, contract interest rates on commitments for fixed-rate first mortgages(30 years), Board of Governors of the Federal Reserve System

10. Nominal output=1-3+5-4-6. The output consists of the consumption and the residential investment but **not** business investment. Because the model we use is an endowment economy, we do not consider the business investment. Hence, we exclude the business investment from the subjects of research and similarly government expenditures.
11. Nominal consumption=2-6. The consumption is composed of non-durable goods, durable goods and services. To be consistent with the model, we subtract the imputed rentals of self-owned houses from the consumption.
12. The ratio of residential investment to personal consumption expenditure=the mean of 5/11
13. The ratio of residential investment to the aggregate house values=the mean of 5/8
14. The ratio of aggregate house values to nominal output=the mean of 8/10
15. Real output=10/7
16. Real consumption expenditure=11/7
17. Real residential investment=5/7

All the real data are detrended with the Hodrick-Prescott filter.

B. Discretizing Two-Dimensional AR(1) Process

We extend the application of the method proposed by Tauchen (1986) from one-dimensional AR(1) process into the following two-dimensional AR(1) process defined by the following

$$\begin{aligned} z' &= \rho z + \nu, \\ s &= \rho z + \eta, \end{aligned}$$

where z is the current productivity, s is the current signal and z' denotes the next-period productivity. The disturbances (ν, η) are i.i.d processes and satisfy the following conditions:

$$
\begin{aligned}
(\nu, \eta) &\perp z \\
(\nu, \eta) &\sim N(0, \Pi),
\end{aligned}
$$

where Π is defined by:

$$
\Pi = \sigma^2 \begin{bmatrix} 1 & \pi \\ \pi & 1 \end{bmatrix}.
$$

Following Tauchen (1986), we assume the members of $\mathcal{Z}$ evenly-spaced and denoted as $\mathcal{Z} = \{z_1, z_2, \ldots, z_{n-1}, z_n\}$ which satisfies

$$
z_1 < z_2 < \cdots < z_n.
$$

The upper and the lower bounds on the range, z_1 and z_n, respectively, are set to m unconditional standard deviations on each side of 0.[6] Therefore, z_1 and z_n satisfy the following

$$
z_1 = -m \frac{\sigma}{\sqrt{1-\rho^2}}
$$

and

$$
z_n = m \frac{\sigma}{\sqrt{1-\rho^2}}.
$$

We also assume the signals $s \in \mathcal{S} = \mathcal{Z}$. If we define the state composed of the current productivity and the signal, i.e. (z, s), the probability transition matrix is determined as follows.

Let $\omega = z_i - z_{i-1}$ $(i > 1)$. Given (z, s), the probability of z' satisfies the following.

[6] 0 is the unconditional mean of z in this paper.

If $1 < i < n$,

$$\text{Prob}(z' = z_i | z = z_m, s = z_h) =$$

$$\text{Prob}(z_i - \omega/2 \leq \rho z_m + \nu \leq z_i + \omega/2 | \eta = z_h - \rho z_m) =$$

$$\Phi\left[\frac{z_i + \omega/2 - \rho z_m - \rho(z_h - \rho z_m)}{\sigma\sqrt{(1-\rho^2)}}\right] - \Phi\left[\frac{z_i - \omega/2 - \rho z_m - \rho(z_h - \rho z_m)}{\sigma\sqrt{(1-\rho^2)}}\right]$$

If $i = 1$,

$$\text{Prob}(z' = z_i | z = z_m, s = z_h) =$$

$$\text{Prob}(\rho z_m + \nu \leq z_1 + \omega/2 | \eta = z_h - \rho z_m) =$$

$$\Phi\left[\frac{z_1 + \omega/2 - \rho z_m - \rho(z_h - \rho z_m)}{\sigma\sqrt{(1-\rho^2)}}\right]$$

If $i = n$,

$$\text{Prob}(z' = z_i | z = z_m, s = z_h) =$$

$$\text{Prob}(\rho z_m + \nu \geq z_n - \omega/2 | \eta = z_h - \rho z_m) =$$

$$1 - \Phi\left[\frac{z_n - \omega/2 - \rho z_m - \rho(z_h - \rho z_m)}{\sigma\sqrt{(1-\rho^2)}}\right]$$

where $\Phi(\cdot)$ denotes the cumulated distribution function of standard normal distribution. Also, we know that given z', the probability of s' satisfies the following:

If $1 < j < n$,

$$P(s' = z_j | z' = z_i) =$$
$$P(z_j - \omega/2 \leq \rho z_i + \eta \leq z_j + \omega/2) =$$
$$\Phi\left[\frac{z_j + \omega/2 - \rho z_i}{\sigma}\right] - \Phi\left[\frac{z_j - \omega/2 - \rho z_i}{\sigma}\right]$$

If $j = 1$,

$$P(s' = z_1 | z' = z_i) =$$
$$P(\rho z_i + \eta \leq z_1 + \omega/2) =$$
$$\Phi\left[\frac{z_1 + \omega/2 - \rho z_i}{\sigma}\right]$$

If $j = n$,

$$P(z' = z_n | z' = z_i) =$$
$$P(\rho z_i + \nu \geq z_n - \omega/2) =$$
$$1 - \Phi\left[\frac{z_n - \omega/2 - \rho z_i}{\sigma}\right]$$

Then the transition probability is defined by

$$\text{Prob}(z', s' | z, s) = \text{Prob}(z' | z, s)\text{Prob}(s' | z').$$

C. Parameters of Income Process

This appendix displays the parameters of the processes of the individual income. The set of states for the individual income process (normalized to 1) is given by

$$\begin{pmatrix} 0.2468 & 0.4473 & 0.7654 & 1.3097 & 2.3742 \end{pmatrix}.$$

And the transition matrix Ω is given by

$$\begin{pmatrix} 0.7367 & 0.2473 & 0.0150 & 0.0002 & 0.0000 \\ 0.1947 & 0.5555 & 0.2328 & 0.0169 & 0.0001 \\ 0.0113 & 0.2221 & 0.5333 & 0.2221 & 0.0113 \\ 0.0001 & 0.0169 & 0.2328 & 0.5555 & 0.1947 \\ 0.0000 & 0.0002 & 0.0150 & 0.2473 & 0.7376 \end{pmatrix}.$$

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Tables

Table 1: Parameters

Preferences	
$\beta = 0.985$	discount factor
$\kappa_h = 0.125$	the weight of housing in utility function
Market	
$r = 5.66\%$	mortgage rate
$r^c = 16.60\%$	credit card rate
$\delta_h = 0.013$	depreciation rate of the houses
$\gamma = 0.820$	$1 - \gamma$ is the down payment required for the mortgage
$\phi = 0.021$	adjustment costs
Productivity	
$\rho = 0.821$	autocorrelation of the aggregate income process
$\sigma_\nu = 0.019$	standard deviation of the aggregate income process

Table 2: Selected Moments

Variable x	Standard deviation	Correlation coefficients of GDP_t with								
		x_{t-4}	x_{t-3}	x_{t-2}	x_{t-1}	x_t	x_{t+1}	x_{t+2}	x_{t+3}	x_{t+4}
Real Data										
GDP	0.02	0.14	0.38	0.61	0.82	1.00	0.82	0.61	0.38	0.14
Consumption	0.01	0.16	0.37	0.58	0.76	0.87	0.80	0.66	0.47	0.26
Residential Investment	0.10	0.41	0.57	0.72	0.81	0.80	0.66	0.47	0.26	0.05
Benchmark Economy: $\gamma = 0.82$ **and** $\pi = 0.8$										
GDP	0.02	0.10	0.32	0.57	0.82	1.00	0.82	0.57	0.32	0.10
Consumption	0.01	0.16	0.41	0.66	0.81	0.88	0.71	0.47	0.26	0.07
Residential	0.12	0.18	0.32	0.44	0.55	0.39	0.26	0.08	-0.02	-0.18
Economy I: $\gamma = 0.82$ **and** $\pi = 0.2$										
GDP	0.02	0.10	0.32	0.57	0.82	1.00	0.82	0.57	0.32	0.10
Consumption	0.00	0.05	0.28	0.55	0.80	0.98	0.83	0.61	0.37	0.16
Residential	0.10	0.23	0.40	0.51	0.60	0.61	0.29	0.12	-0.04	-0.17
Economy II: $\gamma = 0.0$ **and** $\pi = 0.8$										
GDP	0.02	0.10	0.32	0.57	0.82	1.00	0.82	0.57	0.32	0.10
Consumption	0.00	0.14	0.39	0.65	0.90	0.90	0.74	0.51	0.29	0.10
Residential	0.16	0.25	0.41	0.43	0.39	0.46	0.30	0.10	-0.04	-0.17

Figures

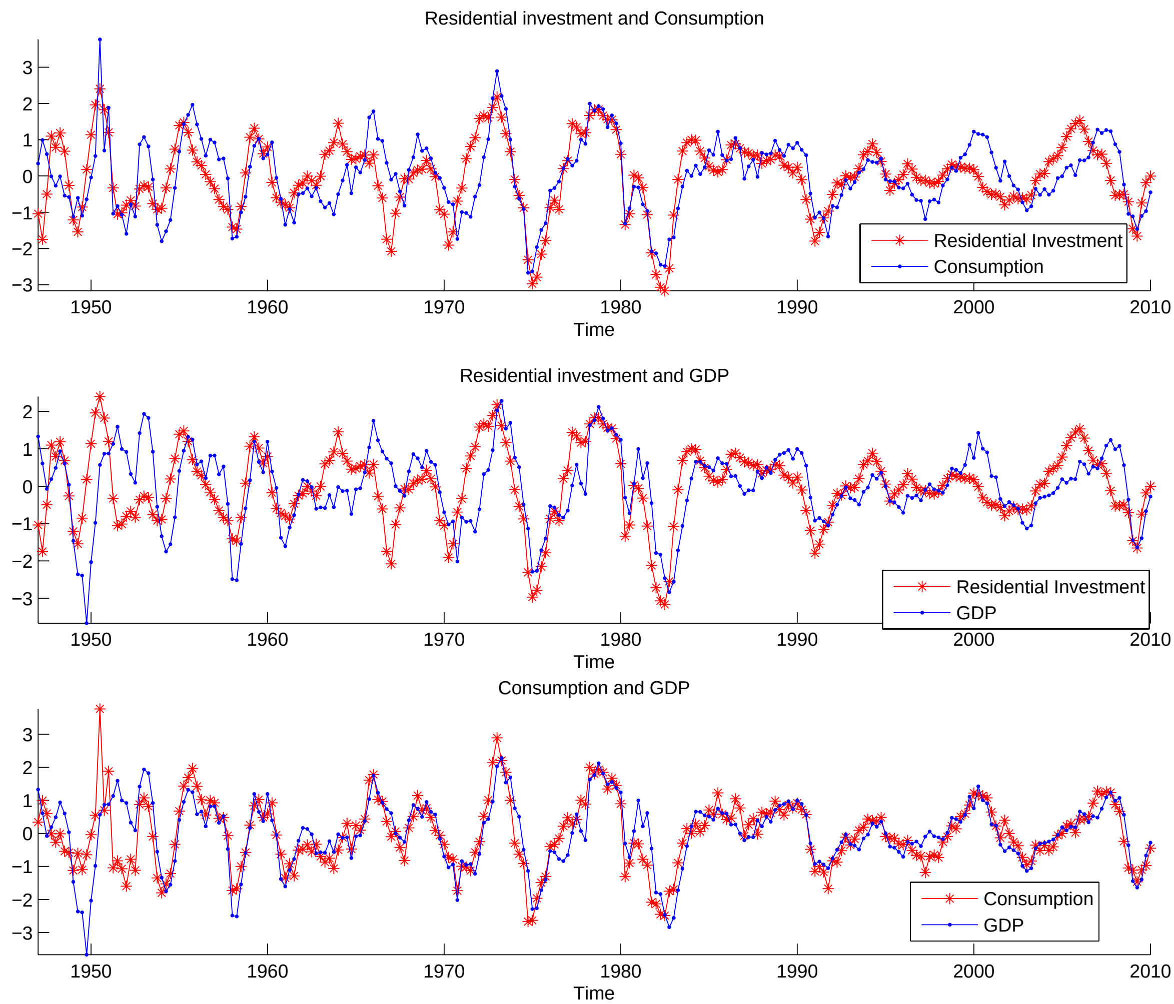

Figure 1: Consumption, Residential Investment, and GDP (1959:Q1-2008:Q4)

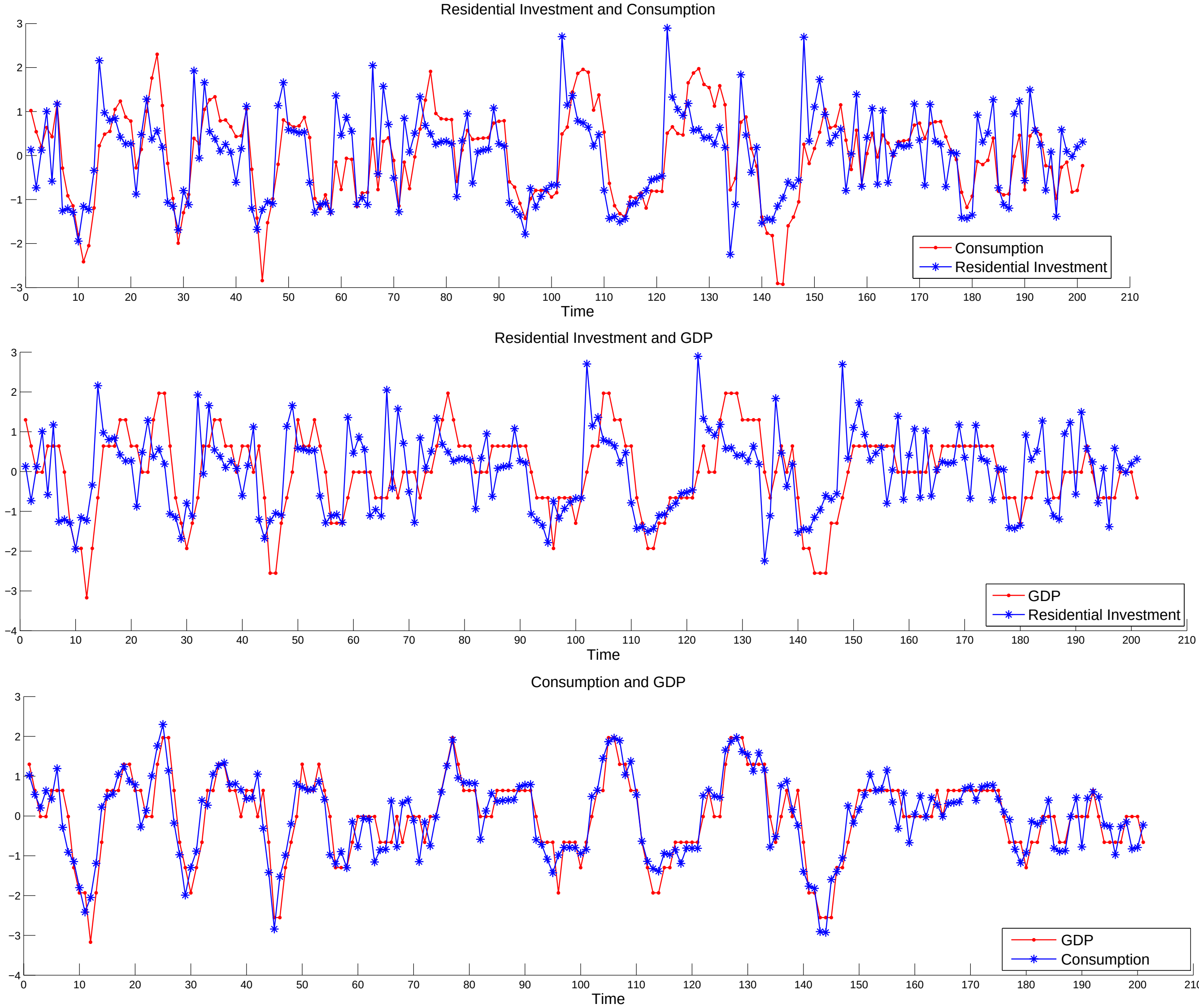

Figure 2: plots the simulated data of GDP, Consumption, Residential Investment in benchmark economy

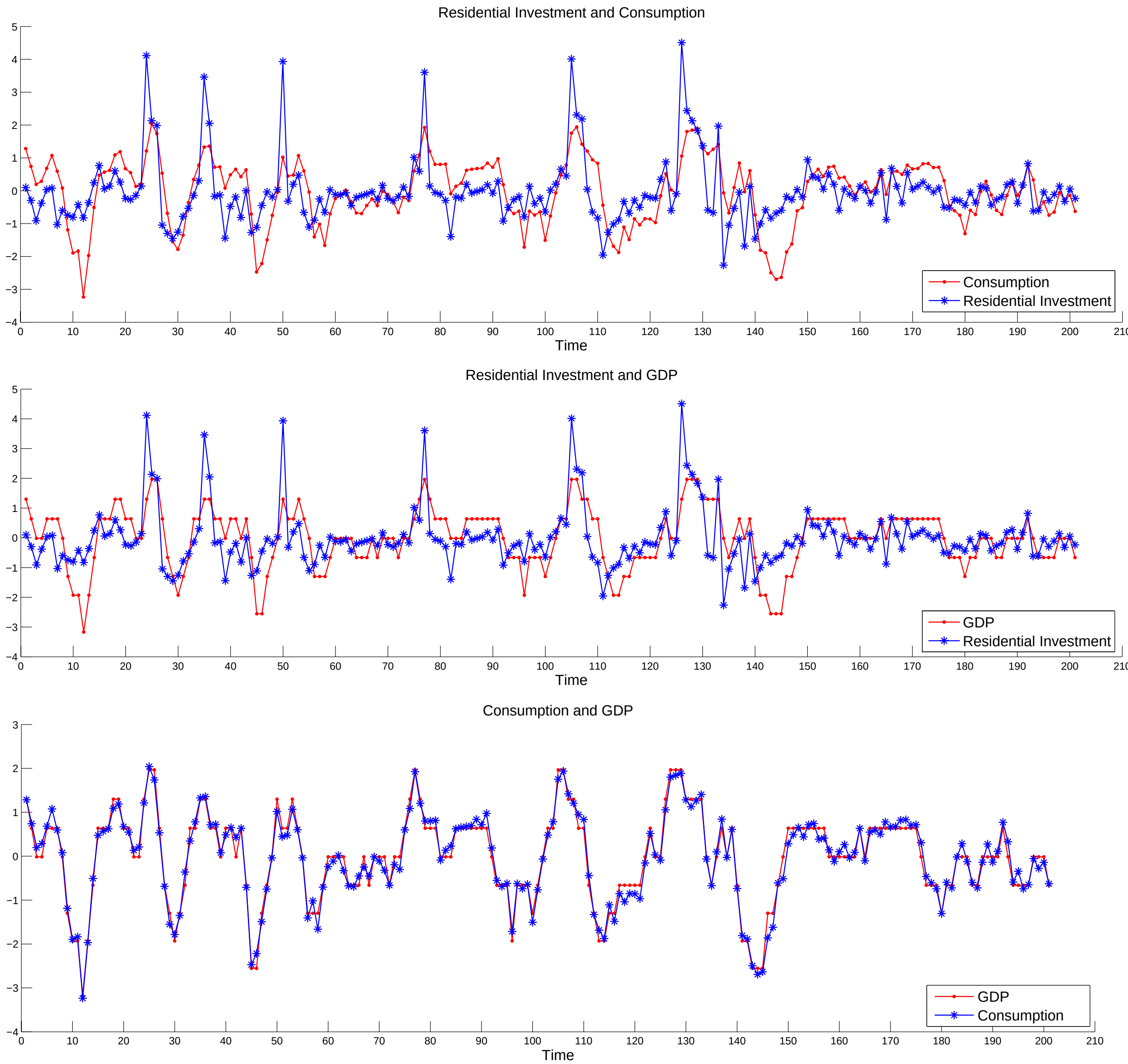

Figure 3: plots the simulated data of GDP, Consumption, Residential Investment in Economy I (weak news)

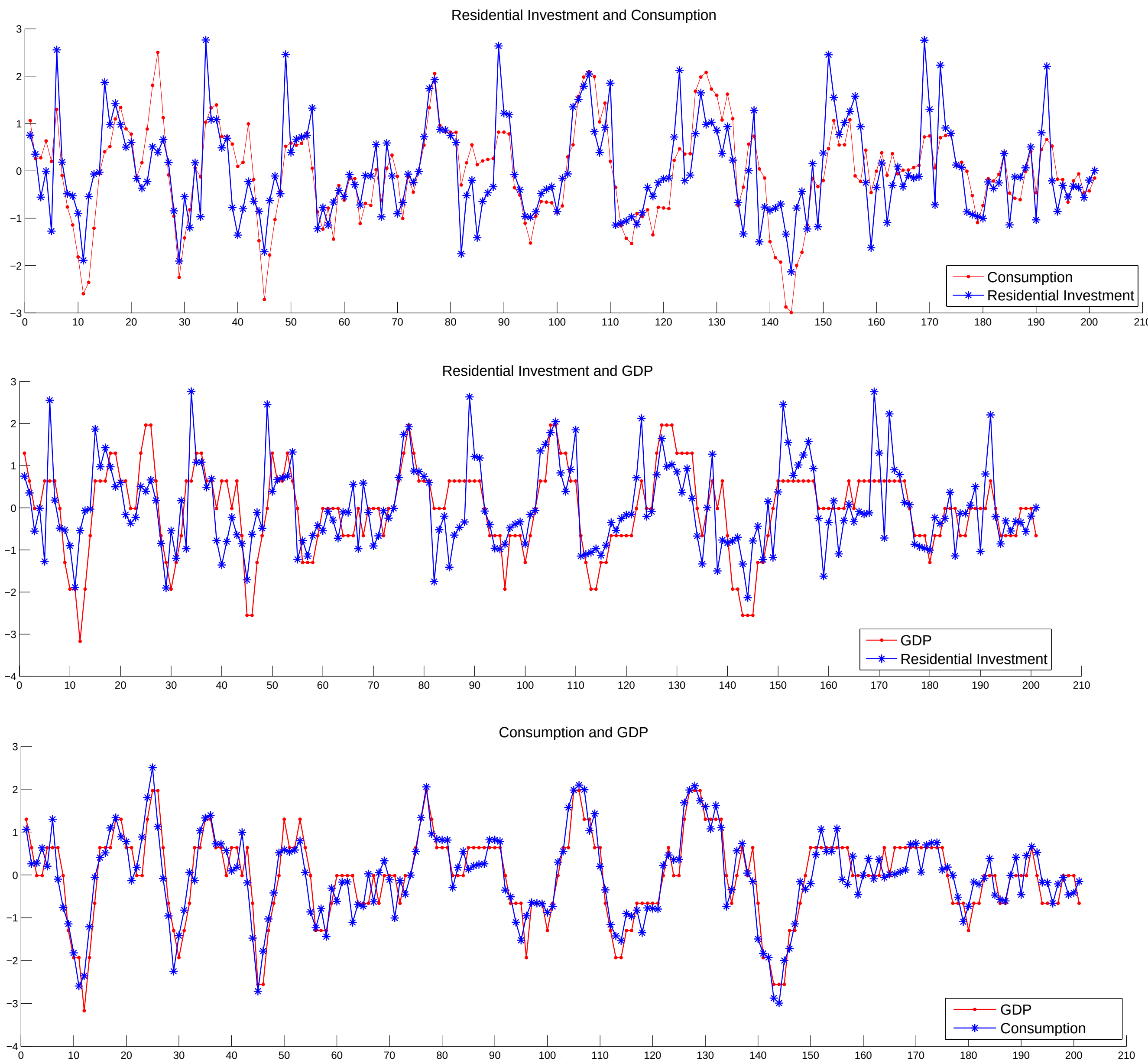

Figure 4: plots the simulated data of GDP, Consumption, Residential Investment in Economy II (no mortgages)