CHAPTER 6

SIMULATION AND RESULTS

This chapter is divided into four sections. In the first section, the simulation results of the base case model as well as the simulation procedure are presented. In Section 6.2, we investigate some variations to the base case model. In Section 6.3, the sensitivity of the results of the base case model to the parameters is analyzed. In the last section, the impulse responses of some key variables in the model to a one-time aggregate productivity shock are reported.

6.1 Base case simulation

The method of solving optimal rules involves approximating the value function for a finite number of states in the state space specified, starting in the last period of life and iterating backward in time to the initial period. In the last period, the only decision to be made is on consumption of non-housing goods, which is straightforward to solve – households consume all the wealth carried over into that period. Specifically, the following steps are taken in the simulation:

Step 1: The h, k, and K space is discretized by a three-dimensional grid.[1] Number of grid points along each dimension is specified such that the results are no longer sensitive to a finer grid.

Step 2: Guess the initial values of $a_N(z)$, $b_N(z)$, $a_K(z)$, $b_K(z)$ for equation (4.16) and (4.17).

Step 3: Starting at the terminal age, the optimal rule is to consume all the holding of housing capital and business capital. The value functions for all possible states are recorded. At the age prior to the terminal age, each possible combination of consumption c, next-period holding of housing capital h', and next-period holding of

[1] The state space consists of six dimensions – housing capital h, business capital k, aggregate business capital K, aggregate shock z, age, and idiosyncratic shock ξ. The variable z (2 possible values), age (60 possible values), and ξ (3 possible values for age 1 to 45 and 1 possible value for age 46 to 60) do not need discretization.

business capital k', is evaluated. The grid of h and k for this purpose can be finer than the grid specified as the state space. For each choice, both the utility in the current-period and the recorded next-period value function is considered and the utility-maximizing choice and the corresponding value function is recorded. In order to get values of the value function off grid points, we interpolate linearly in three dimensions (h, k, and K). Note that the next-period value functions depend on the expected value of aggregate business capital K' as it is one of the state variables. Households are assumed to make the decision as if they know for sure that equation (4.16) will hold. In addition, since there are productivity shocks, the transition probability and the current state of the shock must be taken into consideration in coming up with the expected value of the next-period value functions. The optimal rules are calculated using this backward induction down to age 46 when all households are assumed to take a mandatory retirement.

Step 4: The problem of the working households involves maximization over an additional variable, leisure l. Discretizing l into a finite number of grid points is one way to go but it would require prohibitive storage capacity and computing time to achieve a reasonable level of precision. Instead, we continue to evaluate over two-dimensional grid of h and k, as in the retired period, and solve the households' Euler equation and budget constraint for a given h, k, h', k' (current-period and next-period holding of housing capital and business capital). This approach has an additional benefit of not restricting leisure to lie on a grid. Households are assumed to make the decision as if they know for sure that the aggregate business capital in the next period and the aggregate labor in that period will be in accordance with equation (4.16) and (4.17), respectively. With the above described value function iteration, the optimal rules can be computed for all ages.

Step 5: Once all the decision rules at all possible states are calculated, the model economy is simulated to come up with the new guess of $a_N(z)$, $b_N(z)$, $a_K(z)$, $b_K(z)$ in step 2 based on the aggregate results of the households' decision. The initial distribution of housing capital and business capital for each age, as well as the initial value of aggregate business capital and aggregate shock is assumed. In each period, new households are added with zero business capital and minimum housing capital.[2] The productivity type of the new generation is based on the proportion specified in section 5.2.2. Aggregate shock and idiosyncratic shock is simulated from the random number and the transition probability. To minimize error, the values of the shocks are randomly adjusted to ensure that the proportion of households with different productivity type at each age match the theoretical one implied by the transition probability matrix in equation (5.2). With the known value of shock and the aggregate business capital from the previous period, all the decisions on consumption, investment, and leisure are computed and the resulting aggregate business capital for the next period can be found. Again, linear interpolation in three dimensions (*h*, *k*, and *K*) is used in finding the optimal rules for states off grid points.

Step 6: The time series of the resulting aggregate business capital and employment are used to estimate the new value of $a_N(z)$, $b_N(z)$, $a_K(z)$, $b_K(z)$ by least square. The new guess is a weighted average of the previous guess and the OLS estimation.[3]

Step 7: Repeat step 3 – step 6 until the new values of $a_N(z)$, $b_N(z)$, $a_K(z)$, $b_K(z)$ is close enough to the previous values.

In the base case model, the parameters are calibrated to match the observation of the Thai economy for the period 1980-2005. The parameters used are as summarized in Table 5.4.

The number of grid points for *h*, *k*, and *K* over which the states are specified is 41, 89, and 5, respectively. So, there are a total of 5,473,500 possible states[4] for which the optimal rules are to be solved. The maximum value of *h* and *k* is set at 1.35 and 9.45, both of which are never reached by any households in the simulation. The value of *K* is set to be between 1 and 1.32. The number of grid points for *k* is 89 but

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[2] The holding of housing capital cannot be zero because housing enters the utility function in log form. (i.e. $u(c_i, s_i, l_i) = \theta \ln(c_i) + (1-\theta)\ln(s_i) + \omega \ln(l_i)$ where s_i is the current-period holding of housing capital)

[3] The weight of 0.7 is given to the previous guess.

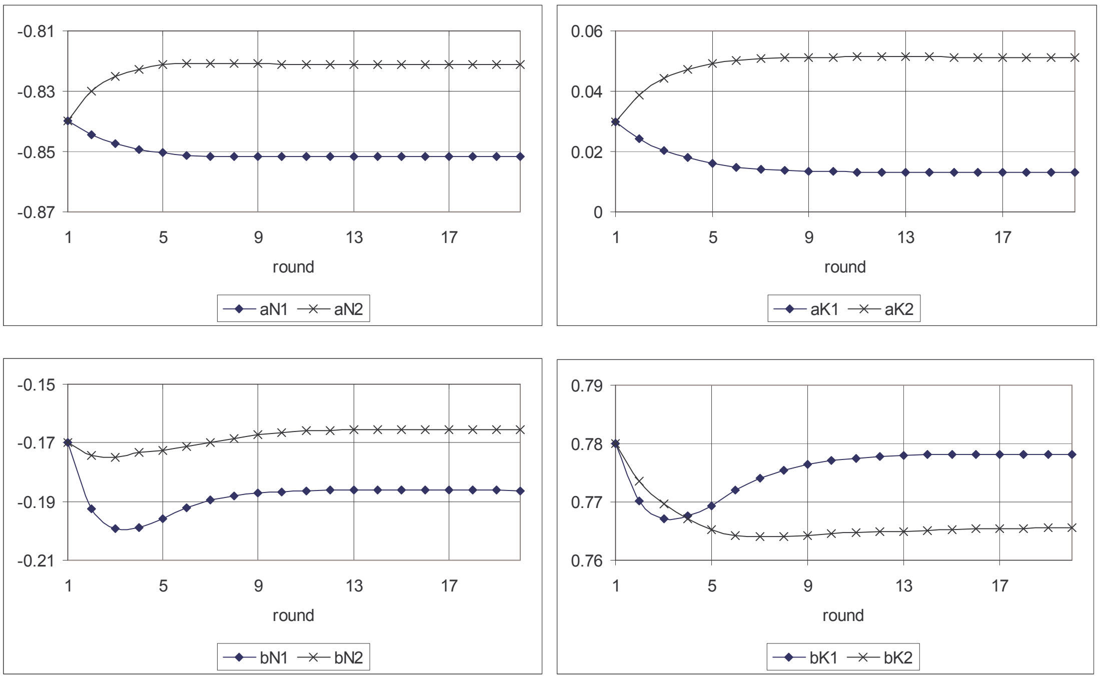
[4] 41 x 89 x 5 x 2 x (45 x 3 + 15 x 1) = 5,473,500

in searching for optimal rules of k we use 5 times finer grid[5]. The economy is simulated for 800 periods with 300 households added in each period. This implies a total of 18,000 households in the economy at any moment.

After repeating step 3 - step 6 for about 20 rounds, $a_N(z)$, $b_N(z)$, $a_K(z)$, $b_K(z)$ series are found to converge to certain values as shown in Figure 6.1.

FIGURE 6.1

Value of $a_N(z)$, $b_N(z)$, $a_K(z)$, $b_K(z)$ from each iteration



It turns out that if households make the following guess about current-period aggregate labor and next-period aggregate business capital (based on the known level of current-period aggregate business capital) in making the decision, the aggregate outcome from all households will match the guess.

For period with negative shock,

$$\begin{bmatrix} \ln N \\ \ln K' \end{bmatrix} = \begin{bmatrix} -0.852 \\ 0.0130 \end{bmatrix} + \begin{bmatrix} -0.186 \\ 0.778 \end{bmatrix} \ln K \qquad (6.1)$$

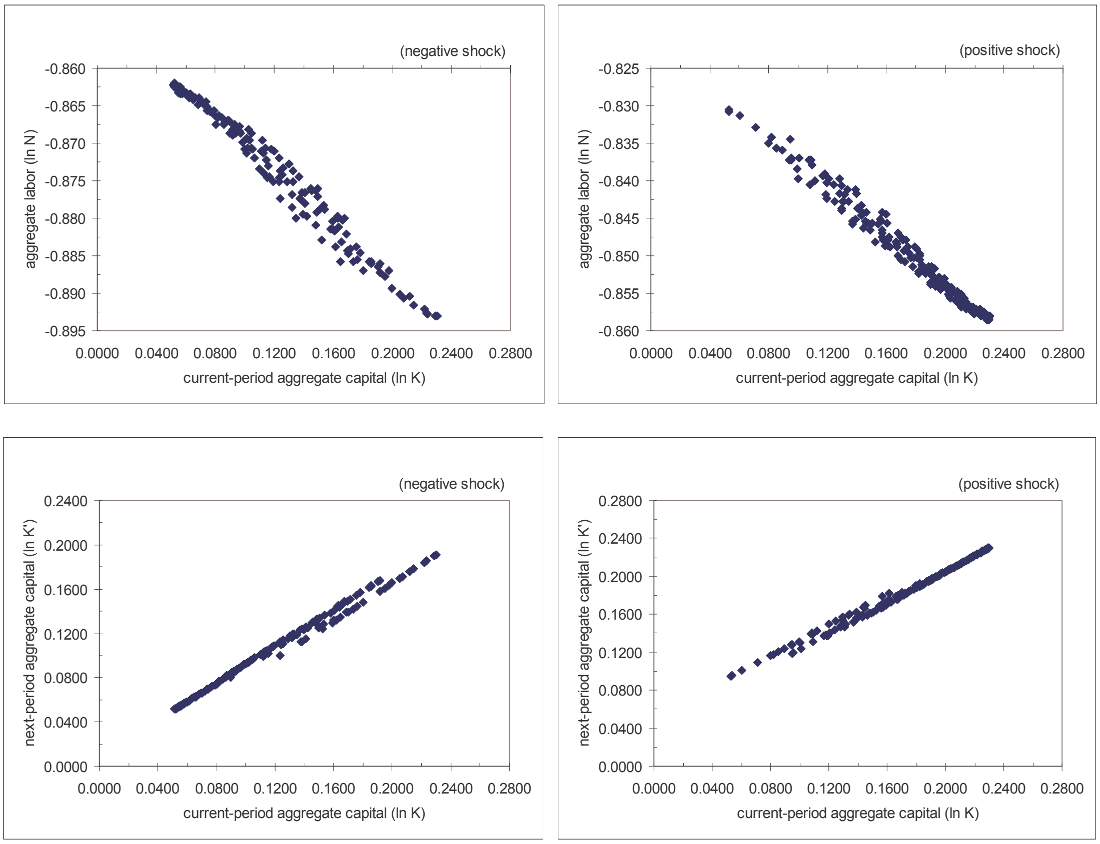
[5] That is, optimal k could take on (89-1) x 5 + 1 = 441 different possible values.

For period with positive shock,

$$\begin{bmatrix} \ln N \\ \ln K' \end{bmatrix} = \begin{bmatrix} -0.821 \\ 0.0513 \end{bmatrix} + \begin{bmatrix} -0.165 \\ 0.766 \end{bmatrix} \ln K \qquad (6.2)$$

FIGURE 6.2

Plot of aggregate labor and next-period aggregate business capital against current-period aggregate business capital when households' guess obeys equation (6.1) and (6.2)



The average error [6] of the guess for aggregate labor is around 0.1% for both periods with negative shock and positive shock as shown in Table 6.1. The maximum error is 0.4%. For guess on next-period capital, the average error of equation (6.1) and (6.2) is 0.2%, with the maximum error of 0.9%.

[6] The error is computed as the absolute value of the difference between the guess and the aggregate outcome divided by the aggregate outcome.

TABLE 6.1

Prediction error of the guess according to equation (6.1) and (6.2)

	Average error	Maximum error
N regression, negative shock	0.1 %	0.4 %
N regression, positive shock	0.1 %	0.3 %
K′ regression, negative shock	0.2 %	0.9 %
K′ regression, positive shock	0.3 %	0.8 %

As can be seen from Table 6.2, the model does a good job of matching the ratio of key variables as a proportion of output to the real economy, especially for the total investment (I_h+I_k), total capital (K+H), and business capital (K). Consumption of non-housing goods (C) from the model is higher; whereas, the housing investment (I_h) and housing capital (H) is lower than the real economy. The proportion of business capital as a percent of total capital ($K/(K+H)$) is 70.2% and 70.6% for the Thai economy and the model economy, respectively. All figures in Table 6.2 are computed at annual frequency[7].

TABLE 6.2

Ratio of some key variables to output of the Thai economy and the base case model

Variable	Thai data (1980-2005)	Base case model
(I_h+I_k)	0.31	0.31
I_h	0.069	0.067
I_k	0.25	0.24
C	0.68	0.69
(K+H)	2.7	2.7
K	1.9	1.9
H	0.82	0.80

Table 6.3 shows the standard deviation of each variable as a ratio to the standard deviation of the output and the correlation of each variable to output. As

[7] For Thai data, the figures are the average of ratio over 1980-2005 period. For the base case model, the figures are the average of ratio across all periods of simulation.

noted in Section 5.3, the variables used in the calculation of Table 6.3 are the deviations around trend after the variables are logged and detrended with Hodrick-Prescott filter[8].

The model produces the standard deviation ratio of total investment, business investment, housing investment, consumption, and employment that do not exactly match the real economy but are within a similar range and of correct order. All the variables in the model are procyclical. Housing investment is not as procyclical as the actual data, whereas employment is more procyclical than the actual data. For total investment, business investment, and consumption of non-housing goods, the model produces correlation close to one, which is in line with actual data. The average proportion of time spent at work of the model is 35.4%, which is close to 35%-36% ratio calculated from the 2005 (Q1–Q4) Labor Force Survey by NSO.

TABLE 6.3

Some business cycle facts of the Thai economy and the base case model

Variable	S.D. of variable / S.D. of output		Correlation with output	
	Thai data (1980-2005)	Base case model	Thai data (1980-2005)	Base case model
(I_h+I_k)	2.2	2.4	0.98	0.98
I_h	3.2	2.9	0.87	0.76
I_k	2.2	2.7	0.99	0.92
C	0.40	0.43	0.93	0.87
N [9]	0.22	0.30	0.53	0.93

Figure 6.3 shows the average housing-to-wealth ratio across age groups from the model and from the 2006 Household Socio-Economic Survey. Wealth in the model is simply defined as housing capital plus business capital. Note that negative business capital will cause housing-to-wealth ratio to be higher than one. In the

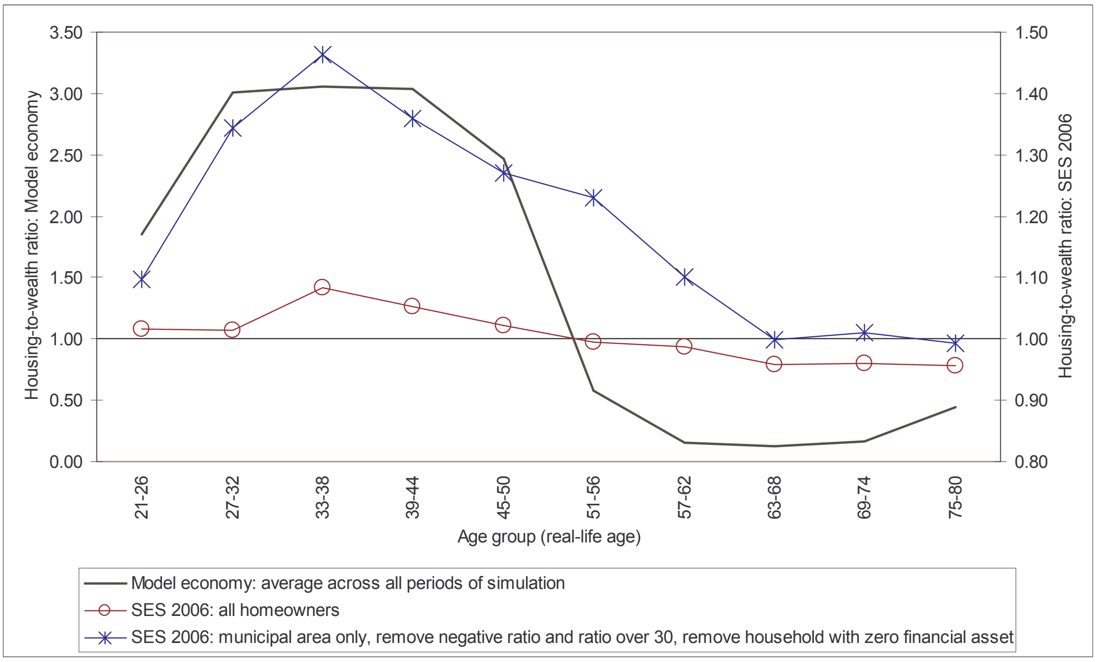
[8] The filter weight used is 100. Theoretically, the filter weight can take any value from zero to infinity. When the filter weight is equal to infinity (zero), the solution to the constrained minimization problem is a linear trend (the original series). At the annual frequency, a value of the filter weight equal to 100 is most often used (Backus and Kehoe (1992), Ravn and Uhlig (1997)).

[9] Thai data on employment is based on Labor Force Survey 1985-2005.

model economy, the ratio is higher than one in the initial stages of life, as shown by the line with no marker. The ratio stays high up to the age of 39-44 years old. After that the ratio starts to drop sharply and becomes lower than one when households reach the age of 51-56 years old as households have to accumulate business capital to consume after retirement.

FIGURE 6.3

Average housing-to-wealth ratio across age group – Household Socio-Economic Survey (2006) vs. Base case model



For the 2006 Household Socio-Economic Survey, we only include households that are homeowners (with the field name 'HH03: tenure' = 1), to be consistent with the model. Housing capital is the field name 'AD01: value of house, land, and building owned by household members for dwelling (for living)'.[10]

[10] There is also a question in the survey asking for estimated rent of the house each household owns ('A40: income in-kind from rental estimate of free-occupied house including own house). At first, we tried to also consider this information in estimating the housing capital of each household. But there are many cases where imputed rents imply housing values that differ very widely from the direct response for housing value. We decide to rely solely on AD01.

Financial assets net of non-business debt is the empirical counterpart of business capital in the model and wealth is defined as the sum of housing capital and business capital. Financial assets are estimated based on the field name 'AD04: value of financial assets', together with 'A33: income from rent of accommodation / land and other properties including license and copyright (average per month)', 'A35: income from saving interests, shares, bonds, and stocks (average per month)', and 'A37: income from *shares* and lending (average per month)'.[11] The non-business debt is the sum of the field name 'AD12: loan from formal sector for purchase / hire-purchase of house and/or land', 'AD14: loan from formal sector for household consumption', 'AD18: loan from informal sector for purchase / hire-purchase of house and/or land', and 'AD20: loan from informal sector for household consumption'. The debt related to business (and farming) is excluded because it is unlikely that the respondent will include the asset side of the business debt as part of the financial asset.[12]

The line with 'o' mark in Figure 6.3 represents the average housing-to-wealth ratio of all homeowners in each age group based on the 2006 Household Socio-Economic Survey. At young ages, the ratio are larger than one but not as large as they are in the base case model. Similarly, the ratio are lower than one but not as low as the base case model. It should be noted that the computed housing-to-wealth ratio of each household within each age group varies very widely, with some even taking negative values.

We also apply a certain filter to the survey data and come up with the line with '*' mark in Figure 6.3. In particular, we exclude households in non-municipal

[11] The field name AD04 indicates a range of value, not a specific value, of the financial asset that the household owns. Therefore, we also need to consider A33, A35, and A37. We estimate the rate of return of return that would cause the implied financial asset base of most household to fall within the range of value according to AD04. For households whose implied financial asset fall within the range, we take the implied value to be the financial assets of that household. For households whose implied financial assets are lower (higher) than the minimum (maximum) value of the range, we take the minimum (maximum) value to be the financial assets of that household.

[12] For example, if the money is borrowed to invest in stocks and the value of stocks are not included in the financial asset, then that money should also not be counted as part of the debt.

areas. This is based on a general observation that behavior of households in non-municipal areas regarding housing decision is very different from that of households in municipal areas and that implied by the setting of the model. Extended family living, where several generations live under the same roof (or in separate houses sharing the same piece of land), is more commonplace in non-municipal areas. Moreover, the way they build their own houses may make it difficult to use them as collateral for borrowing. In addition, we arbitrarily exclude the ratio higher than 30 and below zero. We found the housing-to-wealth ratio for the filtered data to be rising to a peak at the 33-38 year-old age group before declining to the value close to one after the 63-68 year-old age group.

One of the explanations for the more 'extreme' patterns of the model result compared with actual data might be that the model assumes no retirement labor income and self dependence. Households in the model have to make the decision rationally and cannot hope for anyone (including the government and their offspring) to take care of them when they retire. Households in the model have no other way of earning income during retirement other than interest income from savings (i.e. business capital). Moreover, the model assumes all households start their lives with zero wealth, which might not be the case in reality.

Figure 6.4 shows the average holding of housing capital for each age group. The base case model (line with no mark) suggests that households on average accumulate more and more housing capital during their early working years. Housing capital peaks at the 51-56 year-old age group, which is about the peak age of the age efficiency profile presented in Table 5.3. The shape of the graph for the base case model is similar to the 2006 Household Socio-Economic Survey when all homeowners are included (line with 'o' mark). However, when the survey data are filtered with the same criteria used for Figure 6.3, we get a graph that does not share the same pattern very clearly (line with '*' mark).

FIGURE 6.4

Average holding of housing capital across age group – Household Socio-Economic Survey (2006) vs. Base case model

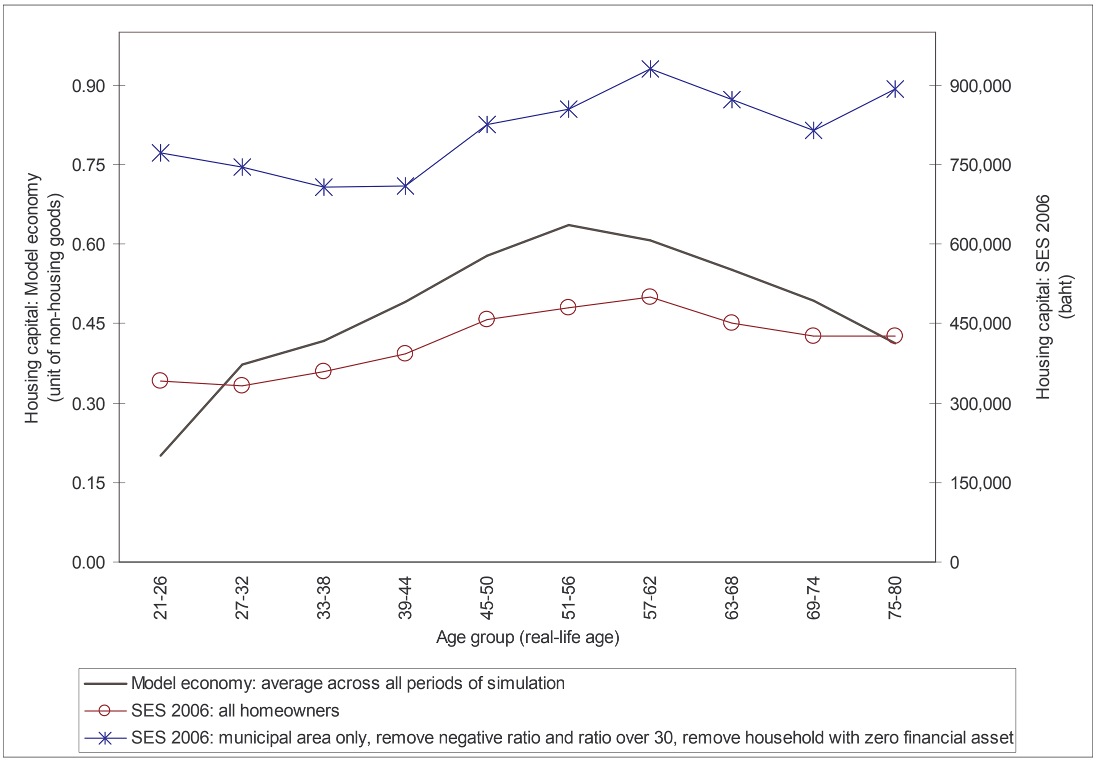


Figure 6.5 shows the average holding of business capital for each age group. Overall, the shape of all the three lines are similar – households are on average net borrowers at young ages and own positive business capital at old ages. According to the base case model, households carry negative business capital up to the 45-50 year-old age group. Business capital holding peaks later in the 63-68 year-old age group, in which all households retire. After that, households start to use up the accumulated business capital.

The housing-to-wealth ratio, housing capital, and business capital of the model economy shown in Figure 6.3 – 6.5 are averaged across many periods of simulation. If the ratio is plotted for each period of simulation, we get the result shown in Figure 6.6.

FIGURE 6.5

Average holding of business capital across age group – Household Socio-Economic Survey (2006) vs. Base case model

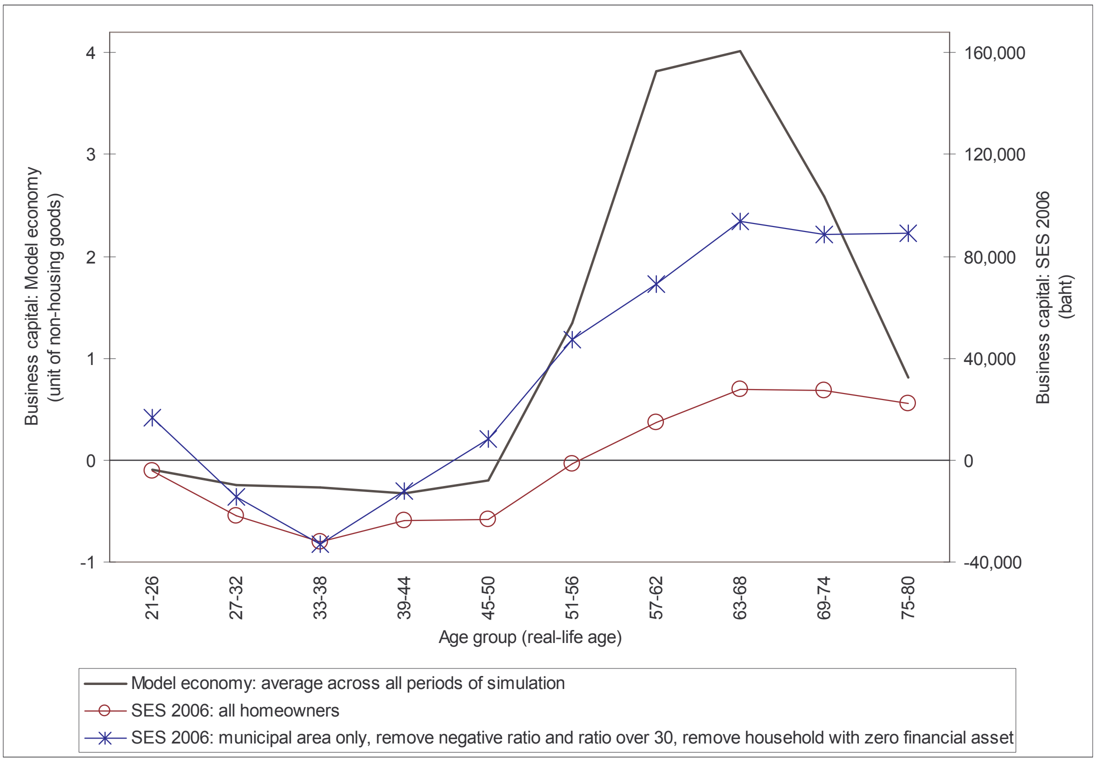
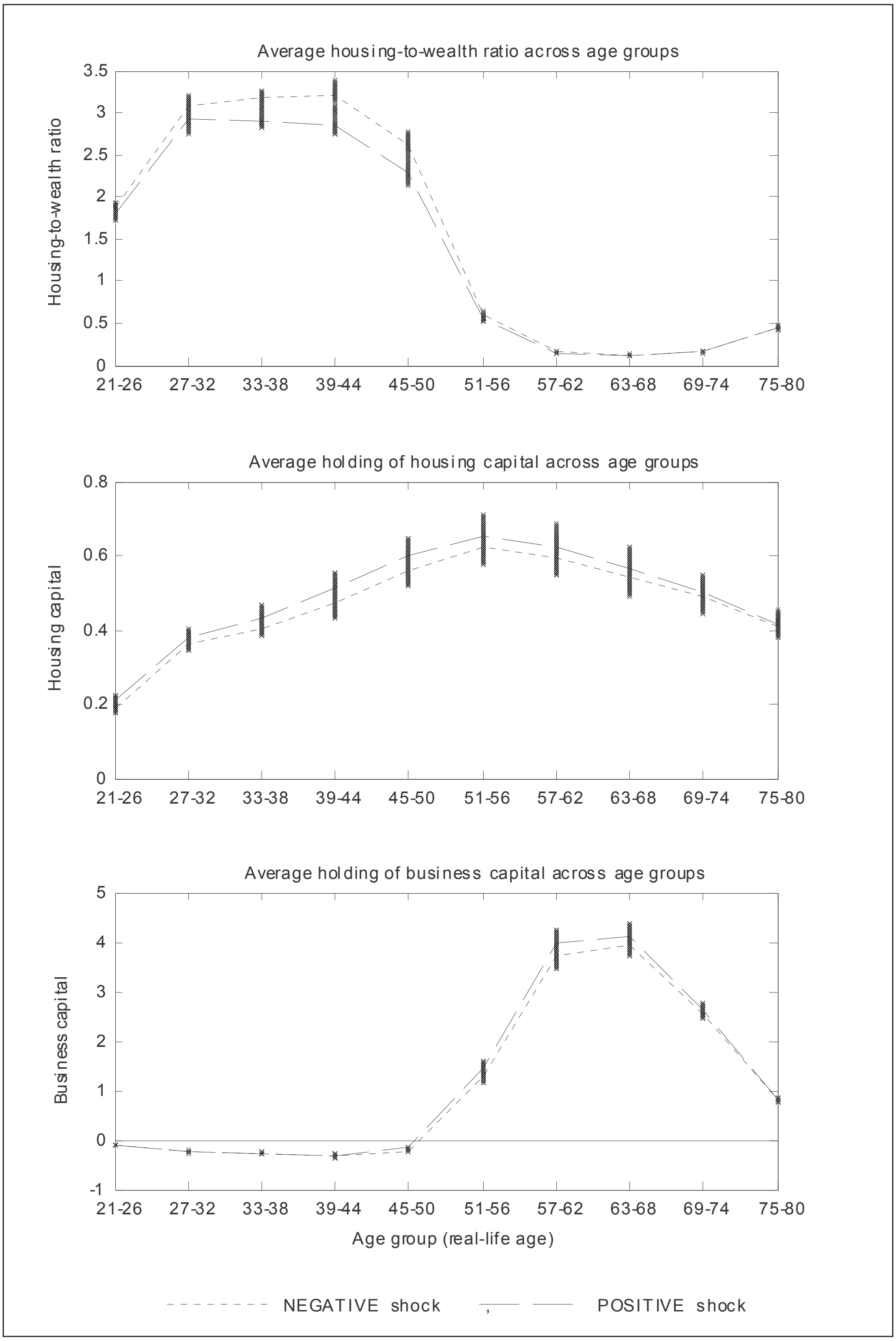


Figure 6.6 shows the average housing-to-wealth ratio, average holding of housing capital, and average holding of business capital across age group, for the base case model. Each 'x' mark represents the average of all households (for each age group) in each period of simulation. The dotted line represents the average of all periods (that follow periods) with negative shock, whereas the dashed line represents the average of all periods (that follow periods) with positive shock.[13]

[13] Since the housing capital and business capital in each period is a result of the investment decision one period earlier, grouping of periods based on shock in the preceding period is more appropriate than grouping based on current-period shock.

FIGURE 6.6

Average housing-to-wealth ratio, housing capital, and business capital across age group – Base case model



The dotted line in the top panel of Figure 6.6 lies above the dashed line at all age groups, meaning that households tend to borrow against a higher proportion of their housing capital in bad years. In the middle panel, the dotted line lies below the dashed line at all age groups, meaning that households tend to hold lower levels of housing capital in bad years. And in the bottom panel, the figure shows that households tend to hold higher levels of business capital in good years than they do in bad years.

The 'x' mark in the top panel of Figure 6.6 lies more dispersedly at young ages than at old ages, meaning that the average housing-to-wealth ratio of all households at old ages do not vary across different periods by as much as at young ages. The middle panel shows that the dispersion of housing capital is high for almost all age groups, whereas the bottom panel shows that the dispersion of business capital is higher at older ages.

All households enter the model with zero business capital and minimal housing capital in every period of simulation. As a result, the variation of average housing-to-wealth ratio, average holding of housing capital, and average holding of business capital in different period of simulation is small in the first (21-26 year-old) age group.

During their working years, households accumulate wealth from labor income and interest income. As Figure 6.6 shows, households tend to adjust their holding of housing capital according to the state of the economy while making a relatively little adjustment to the business capital at young ages. Therefore, there is a big variation in average housing-to-wealth ratio for different period of simulation.

As households approach the retirement period and get closer to the terminal age, the holding of business capital becomes more important as a source of income for retirement. Households then adjust both housing capital and business capital according to the state of the economy, leaving the average housing-to-wealth (of all households) relatively unchanged in different periods of simulation.

In the last (75-80 year-old) age group, the adjustment of business capital becomes less important again since there is not much time left for households to invest and earn interest income. So, we see less variation in average holding of business capital compared with the periods before transition into retirement period.

6.2 Some variations of base case model

In this section, four variations to the base case model are investigated – 1.) model without borrowing, 2.) model with large productivity shock, 3.) model without housing, 4.) model with large productivity shock and without housing, and 5.) model without transaction costs.

6.2.1 Model economy without borrowing

We simulate the model economy similar to the previous section except that we restrict the holding of business capital from being negative. In terms of model parameters, this is equivalent to setting γ to be one, which will make the borrowing constraint in equation (4.6) become $k' \geq 0$.

As can be seen from Table 6.4, when borrowing is not allowed, housing investment and housing capital drops whereas business investment and business capital rise.

TABLE 6.4

Ratio of some key variables to output of the base case model and the model without borrowing

Variable	Base case: $\gamma = 0.3$ (Thai data)	No borrowing: $\gamma = 1$
(I_h+I_k)	0.31 (0.31)	0.32
I_h	0.067 (0.069)	0.065
I_k	0.24 (0.25)	0.25
C	0.69 (0.68)	0.68
(K+H)	2.7 (2.7)	2.8
K	1.9 (1.9)	2.0
H	0.80 (0.82)	0.77

In the base case model, the increase in the holding of housing capital in the following periods, as a result of housing investment in the current period, generates the following benefits in the future. First, it yields higher housing service in the immediate next period. Second, it carries over the wealth into the next period. The housing capital can be converted into non-housing goods although some transaction costs might be incurred. Third, it can serve as collateral to borrow against in temporarily bad times.

This third benefit is what is missing in the model without borrowing which makes it less attractive for households to hold housing capital. Households have to think twice before committing their wealth in housing capital because once purchased the only way to use it as a buffer against negative shocks is to sell it and incur transaction costs. This explains lower housing investment and housing capital as a proportion of output when borrowing is not allowed

As a result, households find it optimal to hold higher business capital, as precautionary savings, to compensate for the missing role of housing capital as a buffer in bad times. With borrowing allowed, households have access to their wealth in housing capital both by borrowing against it and by selling it. Without borrowing, the access to housing capital is only via selling it. Note that it is assumed in the model that households can borrow at the same rate of interest as it earns investing in business capital whereas selling incurs real transaction costs. Therefore, the optimal level of the total wealth in business capital and housing capital rises. This also results in lower consumption of non-housing goods as a proportion of output.

Table 6.5 compares some business cycle facts of the base case model and the model economy without borrowing. The correlation of housing investment to output increases from 0.76 to 0.91 when borrowing is not allowed. This also reflects the missing benefit of housing capital as collateral. Households adjust its holding of housing capital more frequently according to the current state of the economy on the basis of immediate needs for housing service.

TABLE 6.5

Some business cycle facts (standard deviation of variable / standard deviation of output and correlation with output) of the base case model and the model without borrowing

Variable	Base case: $\gamma = 0.3$ (Thai Data)		No borrowing: $\gamma = 1$	
	S.D. ratio	Correlation	S.D. ratio	Correlation
(I_h+I_k)	2.4 (2.2)	0.98 (0.98)	2.4	0.98
I_h	2.9 (3.2)	0.76 (0.87)	3.0	0.91
I_k	2.7 (2.2)	0.92 (0.99)	2.4	0.95
C	0.43 (0.40)	0.87 (0.93)	0.41	0.88
N	0.30 (0.22)	0.93 (0.53)	0.31	0.94

When borrowing is not allowed, households have to be more careful and cannot enjoy larger consumption of non-housing goods as much during the good time. As a result, we see a lower standard deviation ratio of consumption of non-housing goods.

Business investment also moves more in line with output as households tend to accumulate wealth more in the form of business capital and households find it more important to take advantage of higher rate of return during the good economy. Correlation of employment with output rises for similar reason – households are more concerned about bad time and works harder during the good time.

Note that the interpretation of the correlation for employment may not be as straightforward as it seems. Suppose the economy starts off with negative aggregate productivity shock, i.e., the technology level z takes on low value. In the first period that the economy experiences a positive shock, households will find it optimal to supply more labor and invest more in business capital. This is the part where employment moves together with output. In the periods to follow, households enjoy higher interest income on the supplied business capital and may start to find it optimal to consume more leisure. The output will continue to rise due to higher accumulated business capital but the employment may actually fall. Therefore, the resulting correlation also depends pretty much on the path of the aggregate shock, e.g., how often it switches between positive and negative value.

Similar complications occur with business investment and housing investment. The high correlation of both types of investment is the result of a large jump in the same direction as output in the period that the shock switch from negative to positive or from positive to negative. Following the period of switching, they will tend to move in an opposite direction to output because the level of capital has already been adjusted close to the new desired range after the first jump.

Figure 6.7 shows the average housing-to-wealth ratio, average holding of housing capital, and average holding of business capital across age group, for the model without borrowing. Figure 6.8 compares the result in Figure 6.7 with the base case model. Lines with 'o' mark represent the model without borrowing and the lines without mark represent the base case model.

Since business capital cannot be negative, the maximum housing-to-wealth ratio is restricted to be less than or equal to one. The ratio also starts to drop in the 45-50 year-old age group to bottom in the 63-68 year-old age group, and then rise in the last age group. Notice, however, that the gap between average of years with negative shock and years with positive shock is much smaller than the base case model where households are allowed to borrow against their housing capital during bad years.

The shape of the graph for housing capital is similar to the base case model. One thing to notice is that it starts off at lower point at the 21-26 year-old age group but rises to peak at a higher point in the 51-56 year-old age group. Without borrowing, households cannot own large houses at young ages but can finally own larger houses when they mature. For business capital, the peak is still at the 63-68 year-old age group but at lower levels.

FIGURE 6.7

Average housing-to-wealth ratio, housing capital, and business capital across age group – Model without borrowing

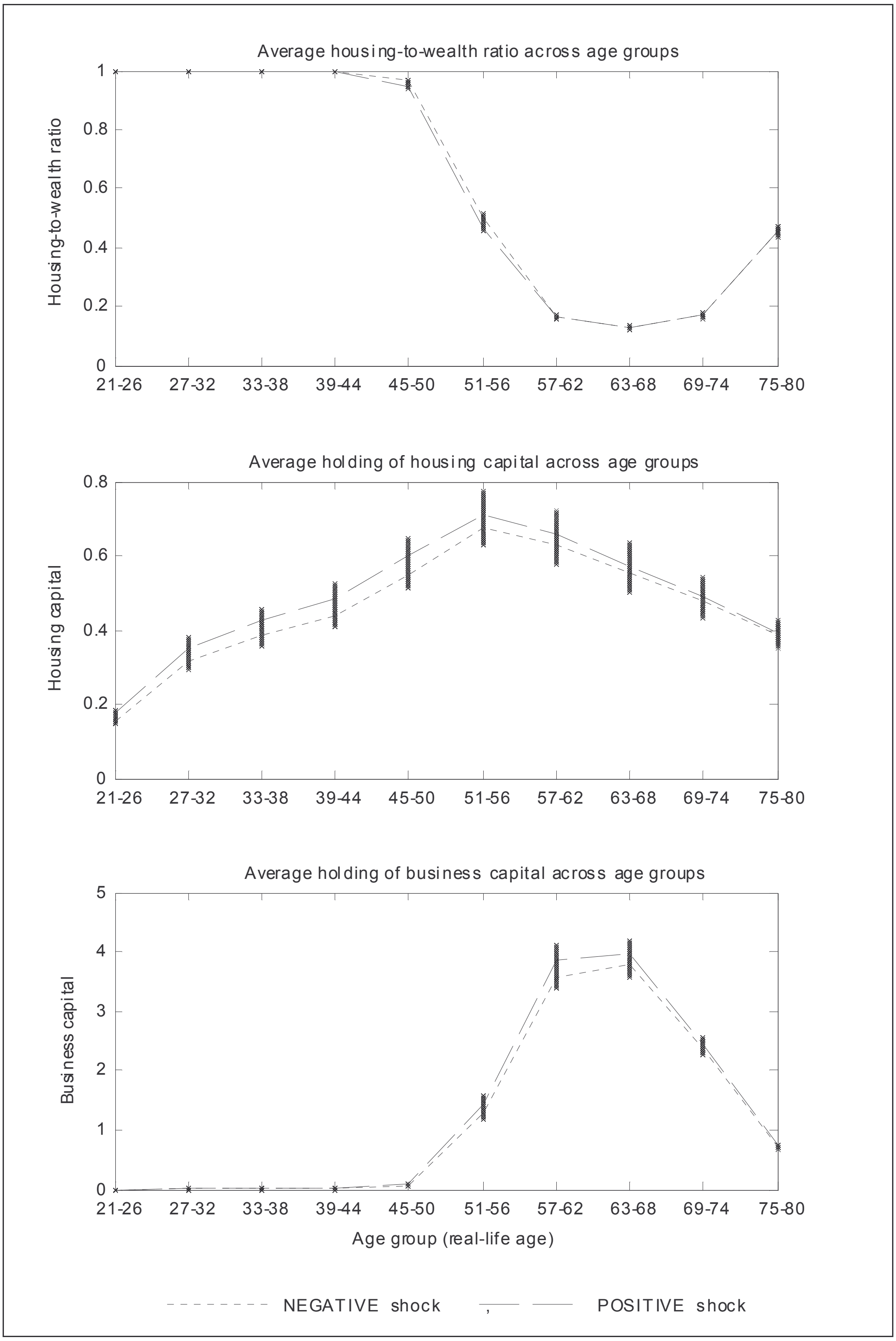
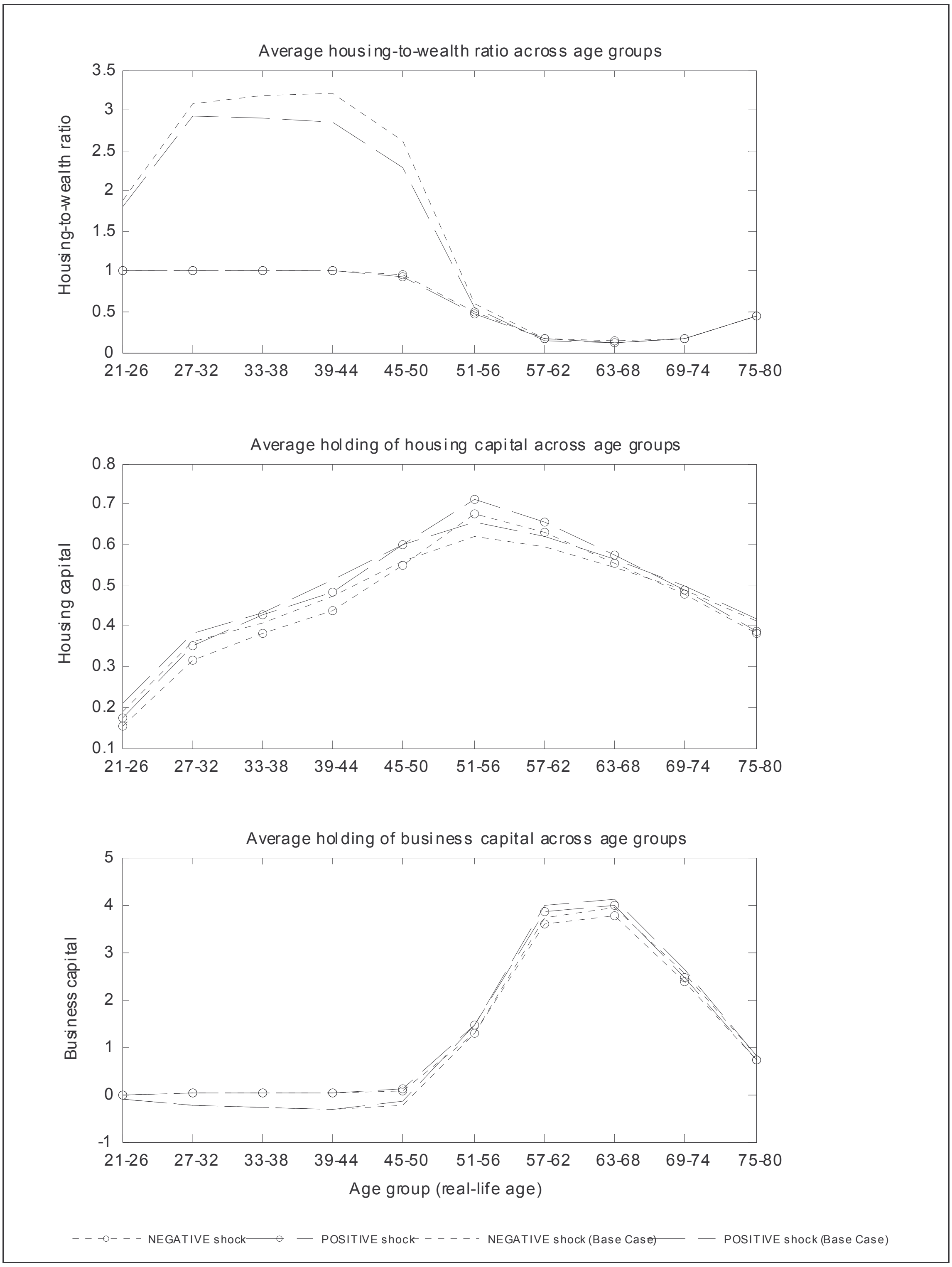


FIGURE 6.8

Comparison of average housing-to-wealth ratio, housing capital, and business capital across age group – Model without borrowing vs. Base case model



6.2.2 Model economy with large productivity shock

We explore the model economy when the magnitude of the aggregate productivity shock becomes larger than the base case model. Specifically, we change the low value of technology level (negative shock) from 0.955 to 0.861 and the high value of technology level (positive shock) from 1.047 to 1.162.[14] The transition probability of the shock remains unchanged.

TABLE 6.6

Ratio of some key variables to output of the base case model and the model with large productivity shock

Variable	Base case: $z \in \{0.955, 1.047\}$ (Thai data)	Large shock: $z \in \{0.861, 1.162\}$
(I_h+I_k)	0.31 (0.31)	0.30
I_h	0.067 (0.069)	0.065
I_k	0.24 (0.25)	0.24
C	0.69 (0.68)	0.70
(K+H)	2.7 (2.7)	2.8
K	1.9 (1.9)	2.0
H	0.80 (0.82)	0.83

According to Table 6.6, the business capital and housing capital as a proportion of output rise when the aggregate uncertainty becomes larger, reflecting the needs for higher precautionary savings. The standard deviation ratio of business investment and housing investment as shown in Table 6.7 becomes significantly larger compared with the base case model. Households take the expectation of the future into consideration when making decisions and the wider range of possibilities

[14] That is from exp(± 0.046),which is derived from empirical data of the Thai economy as described in section 5.2.2, to exp(± 0.15), which is set arbitrarily.

of the future causes the decision today to seem to be less related to the observed current-period shock. Correlation of business investment and housing investment with output fall. For non-housing consumption, the standard deviation ratio and correlation with output of non-housing consumption drop slightly because households can use the accumulated wealth (or borrow against accumulated housing capital) to try to smooth consumption in response to the increase in the magnitude of the aggregate productivity shock.

TABLE 6.7

Some business cycle facts (standard deviation of variable / standard deviation of output and correlation with output) of the base case model and the model with large productivity shock

Variable	Base case: $z \in \{0.955, 1.047\}$ (Thai data)		Large shock: $z \in \{0.861, 1.162\}$	
	S.D. ratio	Correlation	S.D. ratio	Correlation
(I_h+I_k)	2.4 (2.2)	0.98 (0.98)	2.7	0.96
I_h	2.9 (3.2)	0.76 (0.87)	3.9	0.69
I_k	2.7 (2.2)	0.92 (0.99)	3.4	0.84
C	0.43 (0.40)	0.87 (0.93)	0.42	0.85
N	0.30 (0.22)	0.93 (0.53)	0.32	0.92

Figure 6.9 shows the average housing-to-wealth ratio, average holding of housing capital, and average holding of business capital across age group for the model with large productivity shock while Figure 6.10 shows the comparison to the base case model. The pattern of the three graphs are very similar to the base case model but the ratio vary much more widely across different periods of simulation. The larger swing in technology level makes the decision of households more dependent on the current-period productivity shock as well as the historical path. The gap between the line for bad years and good years is also much wider than the base case model.

FIGURE 6.9

Average housing-to-wealth ratio, housing capital, and business capital across age group – Model with large productivity shock

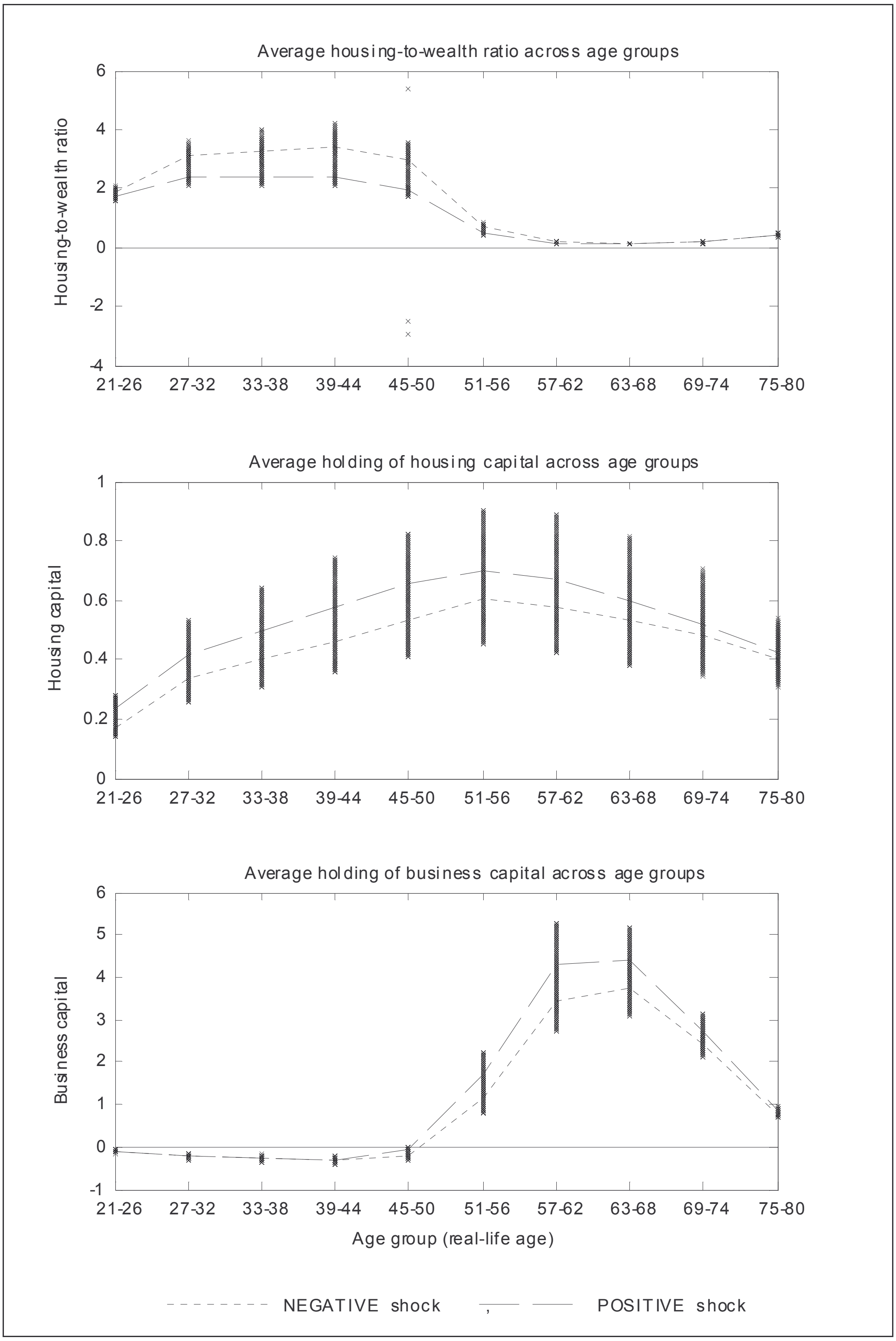
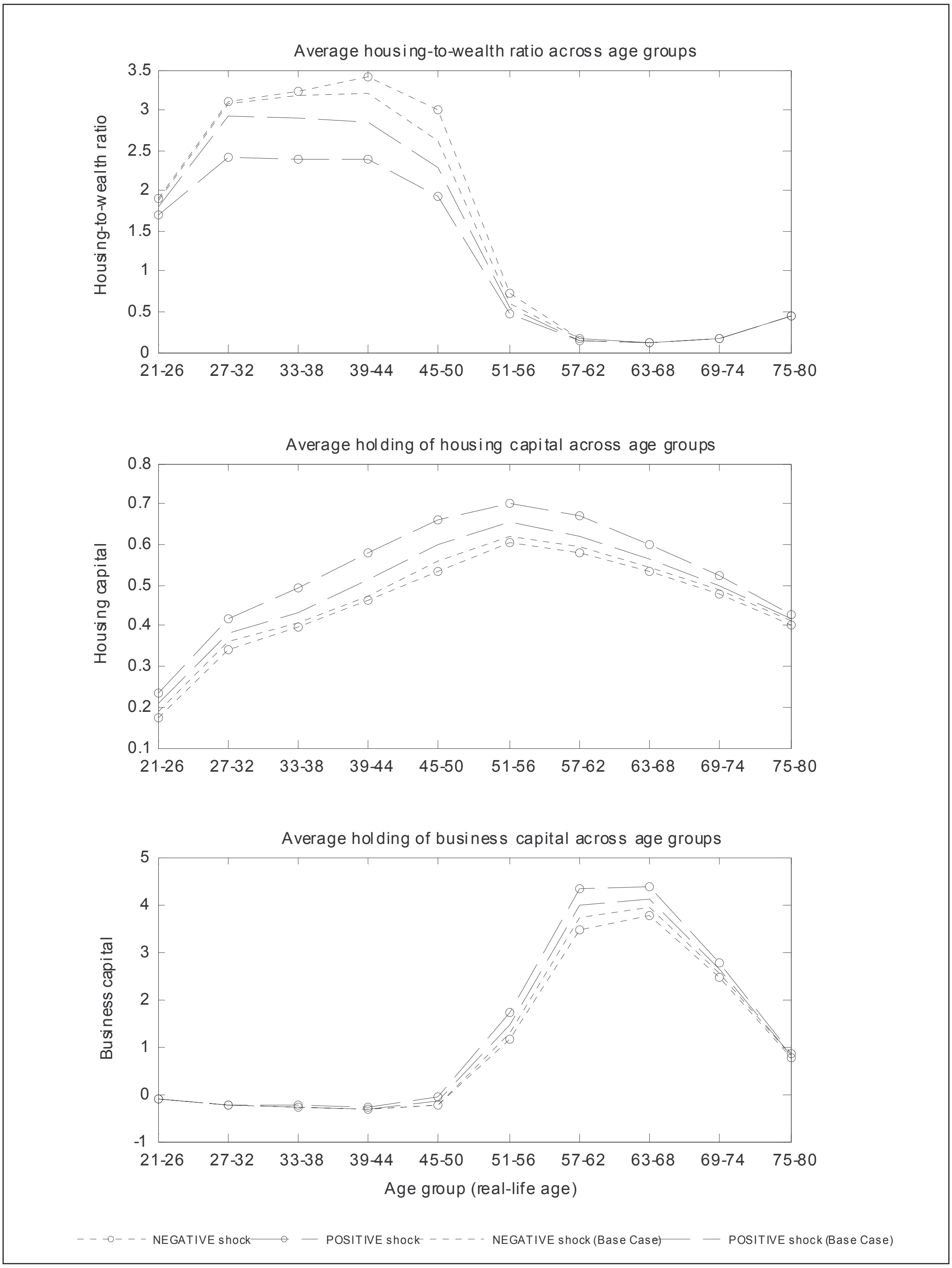


FIGURE 6.10

Comparison of average housing-to-wealth ratio, housing capital, and business capital across age group – Model with large productivity shock vs. Base case model



6.2.3 Model economy without housing

Up to this point, the capital in the model is distinguished between housing capital and business capital. Also, the consumption of non-housing goods and the consumption of housing service are separately identified in the utility function. To explore the model economy without housing, the parameter θ is set to one so that households do not care about housing service. The parameter τ and δ_h are no longer relevant and are both set to zero.

Table 6.8 and 6.9 report the findings of the model economy without housing capital. As would be expected, the business investment rises and moves more in line with output compared to the base case model because households now have no alternative of investing in housing capital. Business capital to output ratio also increases.

TABLE 6.8

Ratio of some key variables to output of the base case model
and the model without housing

Variable	Base case: $\theta = 0.85$ (Thai data)	No housing: $\theta = 1$
(I_h+I_k)	0.31 (0.31)	-
I_h	0.067 (0.069)	-
I_k	0.24 (0.25)	0.26
C	0.69 (0.68)	0.74
(K+H)	2.7 (2.7)	-
K	1.9 (1.9)	2.1
H	0.80 (0.82)	-

TABLE 6.9

Some business cycle facts (standard deviation of variable / standard deviation of output and correlation with output) of the base case model and the model without housing

Variable	Base case: $\theta = 0.85$ (Thai data)		No housing: $\theta = 1$	
	S.D. ratio	Correlation	S.D. ratio	Correlation
(I_h+I_k)	2.4 (2.2)	0.98 (0.98)	-	-
I_h	2.9 (3.2)	0.76 (0.87)	-	-
I_k	2.7 (2.2)	0.92 (0.99)	2.4	0.98
C	0.43 (0.40)	0.87 (0.93)	0.54	0.95
N	0.30 (0.22)	0.93 (0.53)	0.22	0.92

Consumption rises because it now represents all consumption, not just the consumption of non-housing goods as in the base case model. The standard deviation ratio of the consumption increases, showing lower ability to smooth consumption in the absence of housing capital. In addition, the correlation with output of consumption rises as there is no housing capital to buffer the fluctuation in output.

Employment fluctuates to a lower degree compared with the base case model. This is because business investment responds to fluctuation in output more closely. In the periods with positive shock, business capital increases more quickly compared to the base case model and the high interest income in subsequent periods takes away some of the incentive to take advantage of the high wage environment as households will value leisure more.

Figure 6.11 shows the average holding of business capital across age groups for the model without housing and Figure 6.12 compares the model without housing with the base case model. The graph starts rising in the 45-50 year-old age group to peak in the 63-68 year-old age group, which is the beginning of the retirement period.

FIGURE 6.11

Average business capital across age group – Model without housing

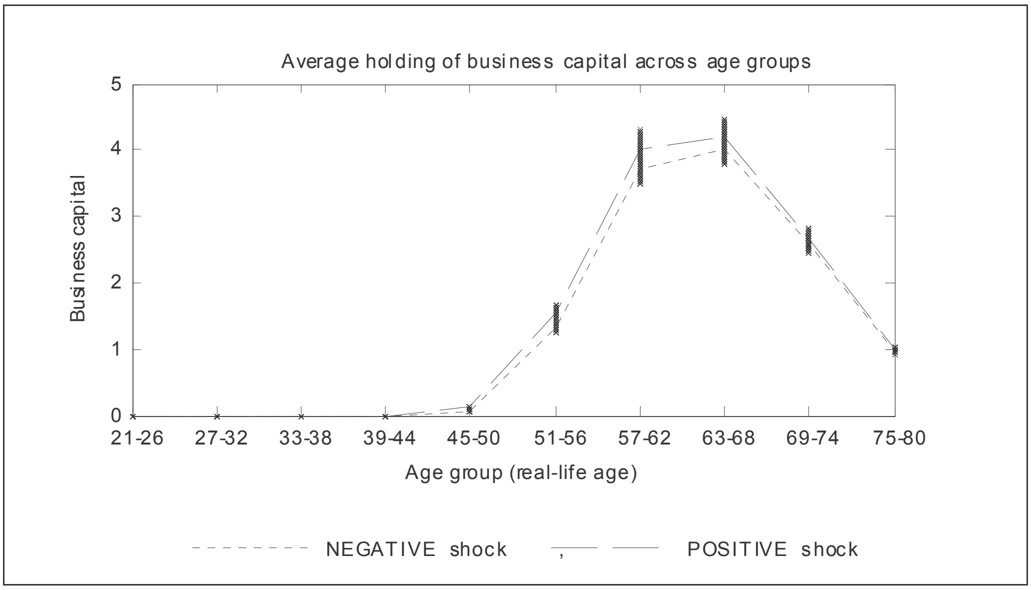
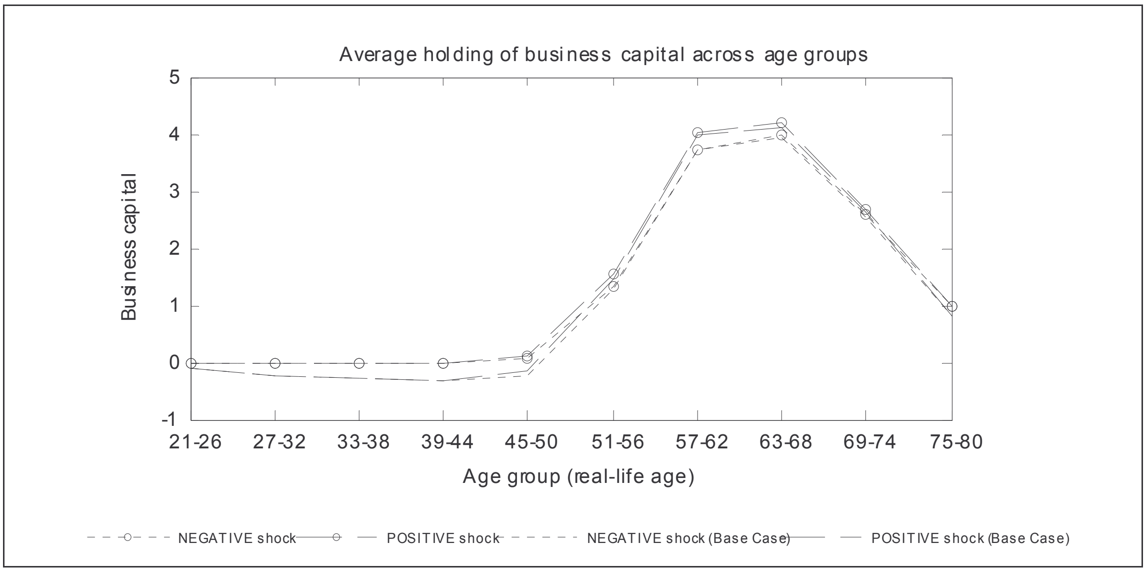


FIGURE 6.12

Comparison of average business capital across age group –
Model without housing vs. Base case model



Since borrowing in the model requires housing as collateral, business capital cannot take a negative value. The average holding of business capital is higher in good years than in bad years for all age groups.

6.2.4 Model economy with large productivity shock and without housing

In this variation of base case model, we simulate the model economy with large productivity shock and without housing capital. This is a mixture of Sections 6.2.2 and 6.2.3 and the focus is on the effect of changing the magnitude of shock in the model with and without housing capital.

TABLE 6.10

Ratio of some key variables to output of the model without housing, with base case shock and with large productivity shock

Variable	Base case shock & No housing: $z \in \{0.955, 1.047\}$, $\theta = 1$	Large shock & No housing: $z \in \{0.861, 1.162\}$, $\theta = 1$
I_k	0.26	0.26
C	0.74	0.74
K	2.1	2.1

TABLE 6.6 (REPRODUCED)

Ratio of some key variables to output of the base case model and the model with large productivity shock

Variable	Base case: $z \in \{0.955, 1.047\}$ (Thai data)	Large shock: $z \in \{0.861, 1.162\}$
(I_h+I_k)	0.31 (0.31)	0.30
I_h	0.067 (0.069)	0.065
I_k	0.24 (0.25)	0.24
C	0.69 (0.68)	0.70
(K+H)	2.7 (2.7)	2.8
K	1.9 (1.9)	2.0
H	0.80 (0.82)	0.83

Tables 6.10 and 6.11 compare the findings of this section to those of Section 6.2.3, to highlight the effect of changing the magnitude of shock in the model without housing.

TABLE 6.11

Some business cycle facts (standard deviation of variable / standard deviation of output and correlation with output) of the model without housing, with base case shock and with large productivity shock

Variable	Base case shock & No housing: $z \in \{0.955, 1.047\}$, $\theta = 1$		Large shock & No housing: $z \in \{0.861, 1.162\}$, $\theta = 1$	
	S.D. ratio	Correlation	S.D. ratio	Correlation
I_k	2.4	0.98	2.7	0.96
C	0.54	0.95	0.52	0.93
N	0.22	0.92	0.25	0.91

TABLE 6.7 (REPRODUCED)

Some business cycle facts (standard deviation of variable / standard deviation of output and correlation with output) of the base case model and the model with large productivity shock

Variable	Base case: $z \in \{0.955, 1.047\}$ (Thai data)		Large shock: $z \in \{0.861, 1.162\}$	
	S.D. ratio	Correlation	S.D. ratio	Correlation
(I_h+I_k)	2.4 (2.2)	0.98 (0.98)	2.7	0.96
I_h	2.9 (3.2)	0.76 (0.87)	3.9	0.69
I_k	2.7 (2.2)	0.92 (0.99)	3.4	0.84
C	0.43 (0.40)	0.87 (0.93)	0.42	0.85
N	0.30 (0.22)	0.93 (0.53)	0.32	0.92

The ratio of variables of interest to output are relatively unresponsive to change in the magnitude of shock. This is also the case for model with housing, as demonstrated in Table 6.6 (reproduced, for convenience). For the standard deviation ratio and correlation with output, the direction of change when larger productivity shock is introduced in the model with housing is similar to the model with housing. The standard deviation ratio of investment and employment becomes larger and the correlation with output becomes smaller with larger productivity shock. On the contrary, the standard deviation ratio of non-housing consumption becomes smaller and the correlation with output becomes larger with larger productivity shock. Table 6.7 is also reproduced here, for convenience.

6.2.5 Model economy without transaction costs

We end this section by exploring the model economy without transaction costs. This is done by setting the parameter τ to be zero. One obvious effect is the overall increase in resource as nothing will be wasted in form of transaction costs. Another effect is the increase in attractiveness of housing investment and housing capital due to lower costs of obtaining and disposing.

TABLE 6.12

Ratio of some key variables to output of the base case model and the model without transaction costs

Variable	Base case: $\tau = 0.25$ (Thai data)	No transaction cost: $\tau = 0$
(I_h+I_k)	0.31 (0.31)	0.31
I_h	0.067 (0.069)	0.069
I_k	0.24 (0.25)	0.24
C	0.69 (0.68)	0.69
(K+H)	2.7 (2.7)	2.7
K	1.9 (1.9)	1.9
H	0.80 (0.82)	0.81

Table 6.12 shows that both housing investment and housing capital rise as a proportion of output when there are no transaction costs compared to the base case model. Other key variables are at similar level to the base case model.

TABLE 6.13

Some business cycle facts (standard deviation of variable / standard deviation of output and correlation with output) of the base case model and the model without transaction costs

Variable	Base case: $\tau = 0.25$ (Thai data)		No transaction cost: $\tau = 0$	
	S.D. ratio	Correlation	S.D. ratio	Correlation
(I_h+I_k)	2.4 (2.2)	0.98 (0.98)	2.4	0.98
I_h	2.9 (3.2)	0.76 (0.87)	5.1	0.47
I_k	2.7 (2.2)	0.92 (0.99)	2.9	0.83
C	0.43 (0.40)	0.87 (0.93)	0.42	0.87
N	0.30 (0.22)	0.93 (0.53)	0.31	0.93

Table 6.13 shows larger standard deviation ratio and lower correlation with output of housing investment and business investment. The standard deviation ratio of housing investment is much larger because households in this variation of the model can freely choose the level of housing capital to hold in the next period without having to consider the current level of housing capital. Note that the transaction costs in the base case model is a quadratic function of the change in housing stock, so gradually changing level of housing capital over several periods is less costly than making large change over one period. Considering the issue raised in Section 6.2.1 about how investment tends to move in the same direction as output only in the first period that the productivity shock changes sign, it can be readily seen that lower correlation of housing investment is the result from households adjusting the housing capital to the level corresponding to new shock all at once, which cause housing investment in the periods to follow less correlated with output. Overall, the absence

of transaction costs only affects how housing investment and business investment move with output but does not affect the total investment, consumption of non-housing goods, and employment so much.

6.3 Sensitivity analysis

In this section, we explore how sensitive the base case model is to changes in some key parameters. Table 6.14 summarizes the six cases being investigated.

TABLE 6.14

Summary of parameters investigated

Section	Parameter	Value: base case	Value: investigated
6.3.1	β : discount factor	0.93	0.91 – 0.95
6.3.2	θ : expenditure share of non-housing goods	0.85	0.80 – 0.90
6.3.3	α : income share of capital	0.35	0.31 – 0.39
6.3.4	δ_k : depreciation rate of business capital	0.128	0.098 – 0.158
6.3.5	δ_h : depreciation rate of housing capital	0.085	0.065 – 0.105
6.3.6	γ : down payment	0.30	0.00 – 0.60

6.3.1 β : discount factor

Discount factor affects how households value future-period utility relative to current-period utility. Higher discount factor implies that households care more about future and should result in higher capital/output ratio as households consume less of what they produce and save more for the future.

TABLE 6.15

Comparison of ratio of some key variables to output – effect of discount factor

Variable	$\beta = 0.91$	$\beta = 0.92$	Base case: $\beta = 0.93$ (Thai Data)	$\beta = 0.94$	$\beta = 0.95$
(I_h+I_k)	0.28	0.30	0.31 (0.31)	0.33	0.35
I_h	0.062	0.065	0.067 (0.069)	0.071	0.074
I_k	0.22	0.23	0.24 (0.25)	0.26	0.27
C	0.72	0.70	0.69 (0.68)	0.67	0.65
(K+H)	2.4	2.6	2.7 (2.7)	2.9	3.0
K	1.7	1.8	1.9 (1.9)	2.0	2.2
H	0.73	0.76	0.80 (0.82)	0.84	0.88

TABLE 6.16

Comparison of standard deviation of some variables relative to standard deviation of output – effect of discount factor

Variable	$\beta = 0.91$	$\beta = 0.92$	Base case: $\beta = 0.93$ (Thai Data)	$\beta = 0.94$	$\beta = 0.95$
(I_h+I_k)	2.6	2.5	2.4 (2.2)	2.4	2.3
I_h	3.2	3.1	2.9 (3.2)	2.9	2.8
I_k	2.8	2.8	2.7 (2.2)	2.6	2.5
C	0.46	0.44	0.43 (0.40)	0.40	0.38
N	0.29	0.30	0.30 (0.22)	0.31	0.32

As discount factor increases, business investment and housing investment, as a ratio of output, increase. Also, households consume less of the output to provide for the higher investment. The business capital and housing capital becomes higher as a result. The standard deviation ratio of consumption of non-housing goods drops as households carry larger business capital and housing capital which can help buffer against fluctuation in output. The correlation of business investment to the output rise because it becomes more beneficial to take advantage of current-period positive shock, for example, when households value future consumption more. The correlation of housing investment with output do not exhibit any trend as different values of discount factor are investigated.

As shown in Tables 6.15 and 6.16, the ratio to output as well as the standard deviation ratio of all key variables are found to be quite sensitive to the discount factor over the range investigated. The correlation with output of most key variables are modestly sensitive to the discount factor except for the aggregate investment, the correlation of which is insensitive to the change in discount factor, as shown in Table 6.17.

TABLE 6.17

Comparison of correlation of some variables relative to output – effect of discount factor

Variable	$\beta = 0.91$	$\beta = 0.92$	Base case: $\beta = 0.93$ (Thai Data)	$\beta = 0.94$	$\beta = 0.95$
(I_h+I_k)	0.98	0.98	0.98 (0.98)	0.98	0.99
I_h	0.75	0.75	0.76 (0.87)	0.74	0.72
I_k	0.91	0.91	0.92 (0.99)	0.92	0.93
C	0.88	0.88	0.87 (0.93)	0.86	0.85
N	0.91	0.92	0.93 (0.53)	0.93	0.94

6.3.2 θ : expenditure share of non-housing goods

This parameter indicates how households value non-housing goods relative to housing service.

Lower θ implies higher importance of housing service and causes the housing investment and housing capital to rise significantly. Households spend less on non-housing goods accordingly. Accumulation of business capital drops slightly as the utility derived from the alternative form of wealth accumulation, i.e. housing capital, rises.

Lowering θ also leads to a drop in the standard deviation ratio and the correlation with output of housing investment. As the role of housing capital in terms of providing housing service in future periods becomes relatively more important compared with the role of just carrying wealth into the future, the decision on how much housing capital to hold involves a longer term consideration. As a result, housing investment becomes less dependent on the current-period shock in output. Moreover, households enter each period with a certain level of housing capital chosen one period before. Since changing the level of housing capital (for the next period) incurs transaction costs and housing service becomes relatively more important directly in the utility function, households must put more weight on the current housing capital (and less weight on current period shock in output) in making decision on consumption of non-housing goods. Consequently, the standard deviation ratio and the correlation with output of consumption of non-housing goods drops.

Because housing investment becomes a better investment with lower θ, households have more incentive to respond to shocks by adjusting the working hours according to the productivity shock. As a result, the standard deviation ratio of employment as well as its correlation with output rise. For business investment, the standard deviation ratio rise whereas the correlation with output falls with lower θ.

As shown in Table 6.18, the ratio to output of housing investment and housing capital are extremely sensitive to this parameter over the range investigated. The ratio to output of total capital is fairly sensitive, whereas this ratio is only slightly sensitive for the total investment, business investment, business capital, and consumption of non-housing goods. In relation to standard deviation ratio, Table 6.19 shows that this parameter almost has no effect on total investment and very little effect on business investment. For housing investment, consumption of non-housing goods, and employment, this parameter plays a moderate role on standard deviation ratio. And finally, this parameter has very little or almost no effect on the correlation to output of all key variables, as shown in Table 6.20.

TABLE 6.18

Comparison of ratio of some key variables to output – effect of expenditure share of non-housing goods

Variable	$\theta = 0.800$	$\theta = 0.825$	Base case: $\theta = 0.85$ (Thai Data)	$\theta = 0.875$	$\theta = 0.900$
(I_h+I_k)	0.33	0.32	0.31 (0.31)	0.30	0.30
I_h	0.091	0.079	0.067 (0.069)	0.056	0.045
I_k	0.24	0.24	0.24 (0.25)	0.25	0.25
C	0.67	0.68	0.69 (0.68)	0.70	0.70
(K+H)	3.0	2.8	2.7 (2.7)	2.6	2.5
K	1.9	1.9	1.9 (1.9)	1.9	2.0
H	1.1	0.93	0.80 (0.82)	0.66	0.54

TABLE 6.19

Comparison of standard deviation of some variables relative to standard deviation of output – effect of expenditure share of non-housing goods

Variable	$\theta = 0.800$	$\theta = 0.825$	Base case: $\theta = 0.85$ (Thai Data)	$\theta = 0.875$	$\theta = 0.900$
(I_h+I_k)	2.4	2.4	2.4 (2.2)	2.4	2.4
I_h	2.8	2.9	2.9 (3.2)	3.1	3.2
I_k	2.8	2.7	2.7 (2.2)	2.6	2.6
C	0.39	0.41	0.43 (0.40)	0.44	0.46
N	0.33	0.32	0.30 (0.22)	0.29	0.28

TABLE 6.20

Comparison of correlation of some variables relative to output – effect of expenditure share of non-housing goods

Variable	$\theta = 0.800$	$\theta = 0.825$	Base case: $\theta = 0.85$ (Thai Data)	$\theta = 0.875$	$\theta = 0.900$
(I_h+I_k)	0.98	0.98	0.98 (0.98)	0.98	0.98
I_h	0.75	0.76	0.76 (0.87)	0.76	0.77
I_k	0.90	0.91	0.92 (0.99)	0.93	0.94
C	0.84	0.86	0.87 (0.93)	0.89	0.89
N	0.93	0.93	0.93 (0.53)	0.92	0.92

6.3.3 α : income share of capital

This parameter specifies the share of output that belongs to the supplier of capital. With higher α, business capital is compensated by higher proportion of output, making carrying wealth in form of business capital become relatively more attractive compared with housing capital. As a result, housing investment and housing capital drops, whereas business investment and business capital rises, as can be seen in Table 6.21. The increase in attractiveness of investing in business capital also makes it optimal for households to reduce consumption of non-housing goods so that it could invest more in business capital.

In each period, after observing the productivity shock in the economy, households have a chance to choose how much labor to supply to earn wage income but it does not have any more chance to change the level of business capital for which it earns interest income. The business capital for that period was chosen in the period before. An increase in α makes interest income a relatively more important source of income compared to wage income. So, total income does not respond to productivity shock by as much. The standard deviation ratio and the correlation with output of housing investment and consumption of non-housing goods fall.

TABLE 6.21

Comparison of ratio of some key variables to output – effect of income share of capital

Variable	$\alpha = 0.31$	$\alpha = 0.33$	Base case: $\alpha = 0.35$ (Thai Data)	$\alpha = 0.37$	$\alpha = 0.39$
(I_h+I_k)	0.30	0.30	0.31 (0.31)	0.32	0.33
I_h	0.071	0.069	0.067 (0.069)	0.065	0.064
I_k	0.23	0.23	0.24 (0.25)	0.25	0.26
C	0.70	0.70	0.69 (0.68)	0.68	0.67
(K+H)	2.6	2.7	2.7 (2.7)	2.8	2.8
K	1.8	1.8	1.9 (1.9)	2.0	2.1
H	0.85	0.82	0.80 (0.82)	0.77	0.75

TABLE 6.22

Comparison of standard deviation of some variables relative to standard deviation of output – effect of income share of capital

Variable	$\alpha = 0.31$	$\alpha = 0.33$	Base case: $\alpha = 0.35$ (Thai Data)	$\alpha = 0.37$	$\alpha = 0.39$
(I_h+I_k)	2.5	2.5	2.4 (2.2)	2.4	2.4
I_h	3.1	3.0	2.9 (3.2)	2.9	2.8
I_k	2.7	2.7	2.7 (2.2)	2.7	2.6
C	0.43	0.43	0.43 (0.40)	0.42	0.41
N	0.30	0.30	0.30 (0.22)	0.31	0.32

As a ratio to output, this parameter has little influence on total investment, consumption of non-housing goods, and total capital; and, it has some influence on housing investment, business investment, housing capital, and business capital.

Changing this parameter over the range investigated has small impact on standard deviation ratio of all variables except housing investment. And finally, the analysis suggests that this parameter has negligible impact on correlation of key variables with output except for housing investment and business investment.

TABLE 6.23

Comparison of correlation of some variables relative to output – effect of income share of capital

Variable	$\alpha = 0.31$	$\alpha = 0.33$	Base case: $\alpha = 0.35$ (Thai Data)	$\alpha = 0.37$	$\alpha = 0.39$
(I_h+I_k)	0.98	0.98	0.98 (0.98)	0.98	0.98
I_h	0.80	0.80	0.76 (0.87)	0.74	0.72
I_k	0.91	0.92	0.92 (0.99)	0.92	0.93
C	0.88	0.88	0.87 (0.93)	0.86	0.85
N	0.93	0.93	0.93 (0.53)	0.93	0.93

6.3.4 δ_k : depreciation rate of business capital

Setting this parameter lower increases the overall resources in the economy and the attractiveness of business investment at the same time.

Table 6.24 shows lower business investment and higher business capital for lower depreciation rate of business capital. The higher net return after depreciation makes business investment more attractive; and so, the optimal level of business capital as a proportion of output rises. However, since part of the business investment is to replace depreciated business capital, a lower depreciation rate leads to lower business investment, even with the increased level of business capital. Housing investment and consumption of non-housing goods rise, as a proportion of output, when less resources are lost through depreciation of business capital.

TABLE 6.24

Comparison of ratio of some key variables to output – effect of depreciation rate of business capital

Variable	$\delta_k = 0.098$	$\delta_k = 0.113$	Base case: $\delta_k = 0.128$ (Thai Data)	$\delta_k = 0.143$	$\delta_k = 0.158$
(I_h+I_k)	0.28	0.30	0.31 (0.31)	0.32	0.33
I_h	0.068	0.067	0.067 (0.069)	0.067	0.067
I_k	0.21	0.23	0.24 (0.25)	0.26	0.27
C	0.72	0.70	0.69 (0.68)	0.68	0.66
(K+H)	3.0	2.9	2.7 (2.7)	2.6	2.5
K	2.2	2.1	1.9 (1.9)	1.8	1.7
H	0.80	0.80	0.80 (0.82)	0.80	0.80

TABLE 6.25

Comparison of standard deviation of some variables relative to standard deviation of output – effect of depreciation rate of business capital

Variable	$\delta_k = 0.098$	$\delta_k = 0.113$	Base case: $\delta_k = 0.128$ (Thai Data)	$\delta_k = 0.143$	$\delta_k = 0.158$
(I_h+I_k)	2.8	2.6	2.4 (2.2)	2.3	2.2
I_h	2.6	2.8	2.9 (3.2)	3.0	3.3
I_k	3.2	2.9	2.7 (2.2)	2.5	2.3
C	0.38	0.41	0.43 (0.40)	0.45	0.45
N	0.33	0.32	0.30 (0.22)	0.29	0.29

TABLE 6.26

Comparison of correlation of some variables relative to output – effect of depreciation rate of business capital

Variable	$\delta_k = 0.098$	$\delta_k = 0.113$	Base case: $\delta_k = 0.128$ (Thai Data)	$\delta_k = 0.143$	$\delta_k = 0.158$
(I_h+I_k)	0.98	0.98	0.98 (0.98)	0.98	0.98
I_h	0.75	0.75	0.76 (0.87)	0.77	0.75
I_k	0.93	0.92	0.92 (0.99)	0.92	0.91
C	0.85	0.86	0.87 (0.93)	0.88	0.88
N	0.94	0.93	0.93 (0.53)	0.92	0.92

With a lower depreciation rate of business capital, the fluctuation of housing investment declines, whereas the fluctuation of business investment rises. This is because households carry more of their wealth into the future (after provided for current-period consumption) in form of business capital as a response to its relatively lower cost of carrying. The correlation of business investment with output rises because there is less friction to taking advantage of higher return in good time. Lower depreciation rate of business capital implies even higher return in good time, which justifies holding larger business capital. The correlation of housing investment with output does not exhibit any trend as different values of depreciation rate of business capital are investigated.

Changing the depreciation rate of business capital over the range specified has negligible impact on housing investment and housing capital and moderate impact on the rest of the key variables, as a proportion of output. It has quite strong impact on standard deviation ratio of most of the key variables except for the consumption of non-housing goods. Correlation of key variables to output change very slightly when we adjust the depreciation rate of business capital over the range shown in Table 6.14.

6.3.5 δ_h : depreciation rate of housing capital

Similar to Section 6.3.4, setting this parameter lower increases the overall resources in the economy and the attractiveness of housing investment at the same time.

A lower depreciation rate of housing capital leads to lower housing investment and higher housing capital. The lower cost of holding housing capital makes it more attractive; and so, the optimal level of housing capital as a proportion of output rises. Since part of the housing investment is to replace depreciated housing capital, a lower depreciation rate leads to lower housing investment, even with the increased level of housing capital. Business investment marginally drops as households substitute business capital with housing capital. Also, consumption of non-housing goods as a proportion of output rises in the amount close to the reduction housing investment and business investment.

TABLE 6.27

Comparison of ratio of some key variables to output – effect of depreciation rate of housing capital

Variable	$\delta_h = 0.065$	$\delta_h = 0.075$	Base case: $\delta_h = 0.085$ (Thai Data)	$\delta_h = 0.095$	$\delta_h = 0.105$
(I_h+I_k)	0.30	0.31	0.31 (0.31)	0.32	0.32
I_h	0.060	0.064	0.067 (0.069)	0.071	0.073
I_k	0.24	0.24	0.24 (0.25)	0.25	0.25
C	0.70	0.69	0.69 (0.68)	0.68	0.68
(K+H)	2.8	2.8	2.7 (2.7)	2.7	2.6
K	1.9	1.9	1.9 (1.9)	1.9	1.9
H	0.92	0.86	0.80 (0.82)	0.75	0.70

TABLE 6.28

Comparison of standard deviation of some variables relative to standard deviation of output – effect of depreciation rate of housing capital

Variable	$\delta_h = 0.065$	$\delta_h = 0.075$	Base case: $\delta_h = 0.085$ (Thai Data)	$\delta_h = 0.095$	$\delta_h = 0.105$
(I_h+I_k)	2.6	2.5	2.4 (2.2)	2.4	2.3
I_h	4.0	3.3	2.9 (3.2)	2.6	2.4
I_k	2.7	2.7	2.7 (2.2)	2.6	2.6
C	0.40	0.42	0.43 (0.40)	0.44	0.44
N	0.32	0.31	0.30 (0.22)	0.30	0.29

TABLE 6.29

Comparison of correlation of some variables relative to output – effect of depreciation rate of housing capital

Variable	$\delta_h = 0.065$	$\delta_h = 0.075$	Base case: $\delta_h = 0.085$ (Thai Data)	$\delta_h = 0.095$	$\delta_h = 0.105$
(I_h+I_k)	0.98	0.98	0.98 (0.98)	0.98	0.98
I_h	0.72	0.75	0.76 (0.87)	0.78	0.81
I_k	0.90	0.91	0.92 (0.99)	0.93	0.93
C	0.86	0.87	0.87 (0.93)	0.87	0.88
N	0.94	0.93	0.93 (0.53)	0.92	0.92

Due to the transaction costs incurred when housing capital holdings change from period to period[15], households have a tendency to maintain the same level of housing capital. With a lower rate of depreciation, it takes less to replace the

[15] Note that even the change in housing capital due to depreciation results in transaction costs in this model economy.

depreciated part of housing capital and households have more freedom to decide how much to invest in housing capital and business capital. As a result, the standard deviation ratio of both types of capital rises.

Changing the depreciation rate of housing capital over the range specified has a negligible impact on the business capital and little impact on total investment, business investment, consumption of non-housing goods, and total capital, as a proportion of output. The effect on ratio of housing investment and housing capital as a proportion of output is moderate. As Table 6.28 demonstrates, this parameter has only little effect on standard deviation ratio of business investment, consumption of non-housing goods, and employment; however, it has an extremely strong effect on the standard deviation ratio of housing investment. For the standard deviation ratio of total investment, the effect is moderate. Correlation of most key variables to output change very slightly when we adjust the depreciation rate of housing capital over the range shown in Table 6.14, with the exception to the housing investment where this parameter has a moderate effect on its correlation with output.

6.3.6 γ : down payment

This parameter indicates the proportion of housing capital that cannot be used as collateral for borrowing. So, a lower γ implies easier access to borrowing. In the base case model, this parameter is set at 0.30, meaning that households can borrow up to 70% of housing capital currently owned.

Overall, it can be seen from Table 6.30 that the ratio of key variables to output are quite unresponsive to the change in this parameter. With a lower γ, housing investment and housing capital tend to be a bit larger, whereas business investment and business capital tend to be a bit smaller. This reflects a higher value of housing capital when a larger proportion is allowed to be used as collateral for borrowing. Consumption of non-housing goods also tends to be higher when households have better access to borrowing.

TABLE 6.30

Comparison of ratio of some key variables to output – effect of down payment

Variable	$\gamma = 0.00$	$\gamma = 0.15$	Base case: $\gamma = 0.30$ (Thai Data)	$\gamma = 0.45$	$\gamma = 0.60$
(I_h+I_k)	0.31	0.31	0.31 (0.31)	0.31	0.32
I_h	0.068	0.068	0.067 (0.069)	0.067	0.067
I_k	0.24	0.24	0.24 (0.25)	0.25	0.25
C	0.69	0.69	0.69 (0.68)	0.69	0.68
(K+H)	2.7	2.7	2.7 (2.7)	2.7	2.7
K	1.9	1.9	1.9 (1.9)	1.9	2.0
H	0.81	0.80	0.80 (0.82)	0.80	0.80

TABLE 6.31

Comparison of standard deviation of some variables relative to standard deviation of output – effect of down payment

Variable	$\gamma = 0.00$	$\gamma = 0.15$	Base case: $\gamma = 0.30$ (Thai Data)	$\gamma = 0.45$	$\gamma = 0.60$
(I_h+I_k)	2.5	2.5	2.4 (2.2)	2.4	2.4
I_h	2.9	2.9	2.9 (3.2)	3.0	3.0
I_k	2.8	2.8	2.7 (2.2)	2.6	2.5
C	0.42	0.42	0.43 (0.40)	0.43	0.43
N	0.31	0.31	0.30 (0.22)	0.30	0.30

TABLE 6.32

Comparison of correlation of some variables relative to output – effect of down payment

Variable	$\gamma = 0.00$	$\gamma = 0.15$	Base case: $\gamma = 0.30$ (Thai Data)	$\gamma = 0.45$	$\gamma = 0.60$
(I_h+I_k)	0.98	0.98	0.98 (0.98)	0.98	0.98
I_h	0.69	0.71	0.76 (0.87)	0.76	0.80
I_k	0.91	0.92	0.92 (0.99)	0.92	0.93
C	0.86	0.86	0.87 (0.93)	0.88	0.88
N	0.93	0.93	0.93 (0.53)	0.93	0.93

The standard deviation ratio of total other key variable are only slightly responsive to change in this parameter. Correlation with output of housing investment fall with a lower γ because households can borrow more in bad years instead of having to reduce the housing capital holdings to make up for the shortfall in output. For other variables, correlation with output are almost unchanged with different values of γ.

6.4 Business cycle dynamics

In this section, the impulse responses of business capital and employment as well as non-housing consumption and housing capital to aggregate productivity shock are explored. To start with, we compute the endogenous variables K, N, C, and H in the non-stochastic steady state characterized by a constant technology level equal to one. In addition, the individual heterogeneity and the idiosyncratic shock in productivity within the same age is assumed away – so, all households have ξ equal to one.

6.4.1 Non-stochastic steady state

To solve for non-stochastic steady state, we use a procedure similar to the one described in Section 6.1. We, however, no longer rely on equation (4.16) and (4.17) in predicting the current-period aggregate labor and next-period aggregate business capital. Instead, we make an initial guess of the steady state aggregate labor and let the households make the decision as if it will be the same in all future periods. For aggregate business capital, we still use the grid approach and compute the optimal rules on all the grid points, assuming for each grid point that the aggregate business capital will remain unchanged from that grid point in all future periods. The procedure can be described as follows:

Step 1: The h, k, and K space is discretized by a three-dimensional grid[16]. Number of grid points along each dimension is specified such that the results are no longer sensitive to a finer grid.

Step 2: Guess the initial values of aggregate labor.

Step 3: Similar to the procedure explained in Section 6.1, we begin by finding the optimal rules and the corresponding value functions for all possible states at the terminal age and work backward to the initial age. For the purpose of finding the optimal rules, the aggregate labor is forecasted to be fixed as guessed in step 2 and the next-period aggregate business capital is forecasted to be the same as in the current period.

Step 4: The model economy is simulated based on the optimal rules in step 3. The initial distribution of housing capital and business capital for each age, as well as the initial value of aggregate business capital is assumed. In each period, new households are added with zero business capital and some minimum housing capital. The aggregate business capital for the next period is based on the decision made by all households in the current period. If the grid of K covers the steady state value of aggregate business capital (based on the guessed value of aggregate labor), the

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[16] The state space consists of only four dimensions – housing capital h, business capital k, aggregate business capital K, and age, as we now fix z and ξ to be one in all periods.

aggregate business capital will converge to that value as we keep on simulating. For the states off grid points, linear interpolation in three dimensions (h, k, and K) is used.

Step 5: The aggregate labor resulting from the households' decisions will also converge to a certain value, whether it be close to the initial guess in step 2 or not. The new guess of aggregate labor is some weighted average of the previous guess and this value.

Step 6: Repeat step 3 – step 5 until the new guess of aggregate labor is close enough to the previous value.

Table 6.33 below reports the non-stochastic steady state value of key variables in the simulation of the base case model, which implies the gross rate of return on capital (before depreciation) of 18.9% and the wage rate of 0.905.

TABLE 6.33

Non-stochastic steady state value of selected variables in the simulation

Variable	Non-stochastic steady state value
K	0.948
H	0.400
C	0.357
N	0.368

6.4.2 Impulse responses

Starting from the steady state in Section 6.4.1, we explore the path along which the economy of the base case model will move in response to a one-time positive aggregate shock to the technology level. In the period of the shock, the log of technology level unexpectedly rises from zero to one. Following the period of the shock, the technology level is assumed to follow a deterministic AR(1) path with the autoregressive coefficient of 0.658, as estimated in section 5.2.2. The following steps are taken:

Step 1: Guess the number of transition periods before aggregate business capital and aggregate labor converge closely enough to the steady state values.

Step 2: Compute the deterministic time path of technology level following the shock.

Step 3: Guess the time path of aggregate business capital and aggregate labor.

Step 4: The h, k, and K space is discretized by a three-dimensional grid.[17] Number of grid points along h and k dimension is specified such that the results are no longer sensitive to a finer grid. Grid points along the K dimension are the aggregate business capital along the time path guessed in step 3.

Step 5: Similar to the procedure explained in Section 6.1, we begin by finding the optimal rules and the corresponding value functions for all possible states at the terminal age and work backward to the initial age. The optimal rules are computed under the assumption that the aggregate business capital and aggregate labor will follow the path guessed in step 3. Beyond the final transition period, households make optimal decision assuming that the aggregate business capital and aggregate labor will remain unchanged.

Step 6: The model economy is then simulated based on the optimal rules in step 5 over the specified transition period. In the first period, the distribution of housing capital and business capital for each age as well as the initial value of aggregate business capital is based on the steady state simulation in Section 6.4.1. In each period, new households are added with zero business capital and some minimum housing capital. The next-period aggregate business capital and the current-period aggregate labor based on the decision made by all households are recorded. However, the decision in the subsequent periods is not based on the resulting aggregate business

[17] The state space consists of only four dimensions – housing capital h, business capital k, aggregate business capital K, and age. For each value of K, there is a corresponding value of z based on the computation in step 2 and the guess in step 3. The variable ξ is fixed at one in all periods.

capital but on the guess in step 3. The optimal rules for the states off grid points are computed by linear interpolation in two dimensions (*h* and *k*).[18]

Step 7: The recorded capital and labor based on the aggregate decision is used to update the guess in step 3, by weighted averaging with the previous guess.

Step 8: Repeat step 4 – step 7 until the new guess of aggregate business capital and aggregate labor is close enough to the previous guess.

Step 9: If it turns out that the aggregate business capital and aggregate labor in the last period of transition do not converge closely enough to the steady state values, increase the number of transition periods guessed in step 1 and repeat step 2 – step 9.

We set the number of transition periods before aggregate business capital and aggregate labor converge to be 40 and make the knowingly-wrong guess that the aggregate business capital and aggregate labor K and N would be equal to the steady state values throughout the periods.

The impulse responses of the technology level z, output Y, business capital K, housing capital H, employment N, and consumption of non-housing goods C are presented in Figure 6.13.

In the first period of shock, technology level jumps[19] from 1 to 2.72 but the output jumps to 319% of the steady state value. This is because households respond to the technology shock by increasing the hours worked (i.e. consume less leisure) to take advantage of 'temporarily' high wage rates. Employment rises 28% in the first period. The aggregate business capital and housing capital remain at the steady state value because they are based on the decision prior to the shock. The consumption of non-housing goods jumps 70% in the first period of the shock as households receive higher wage income and return on invested business capital.

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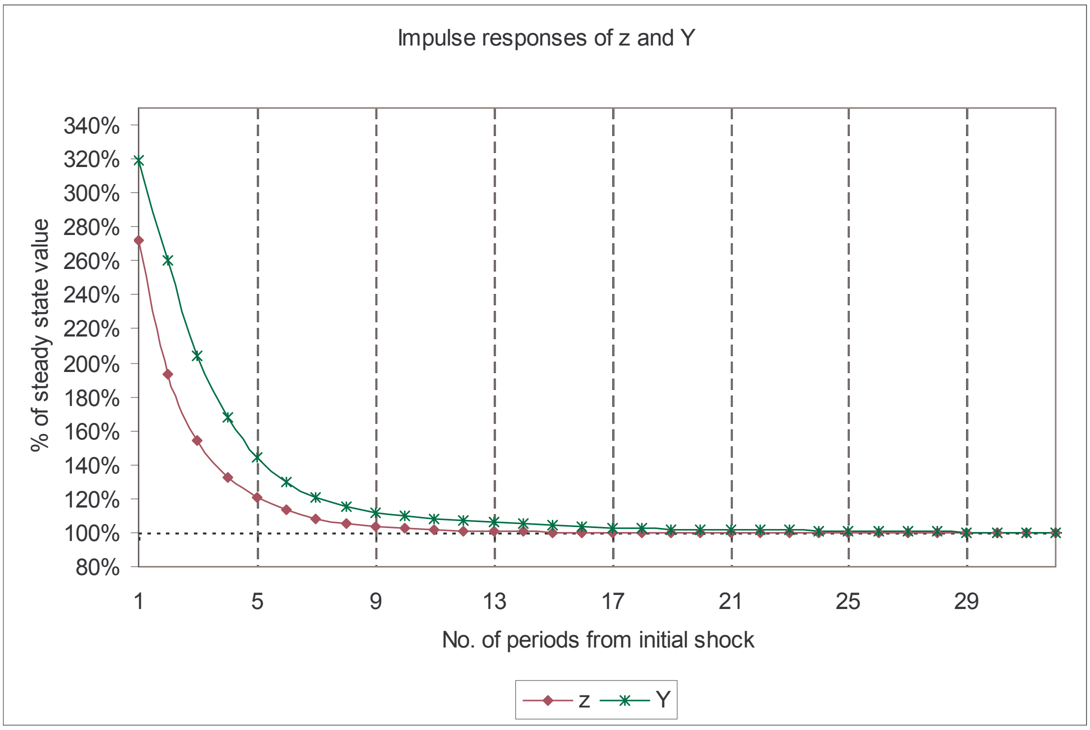
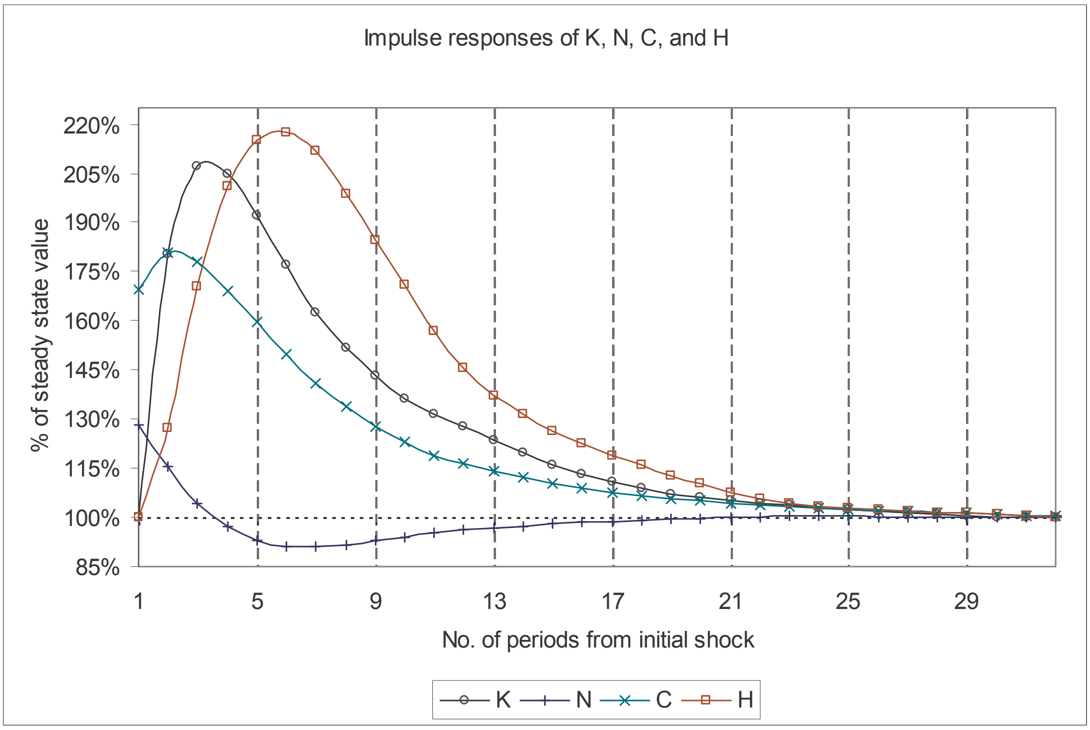
[18] There will be no need to interpolate along the K dimension as we are using K from the guess in step 2, not the resulting K from the aggregate decision.

[19] Log of the technology jumps from zero to one.

FIGURE 6.13

Impulse responses in the model with housing capital – positive shock





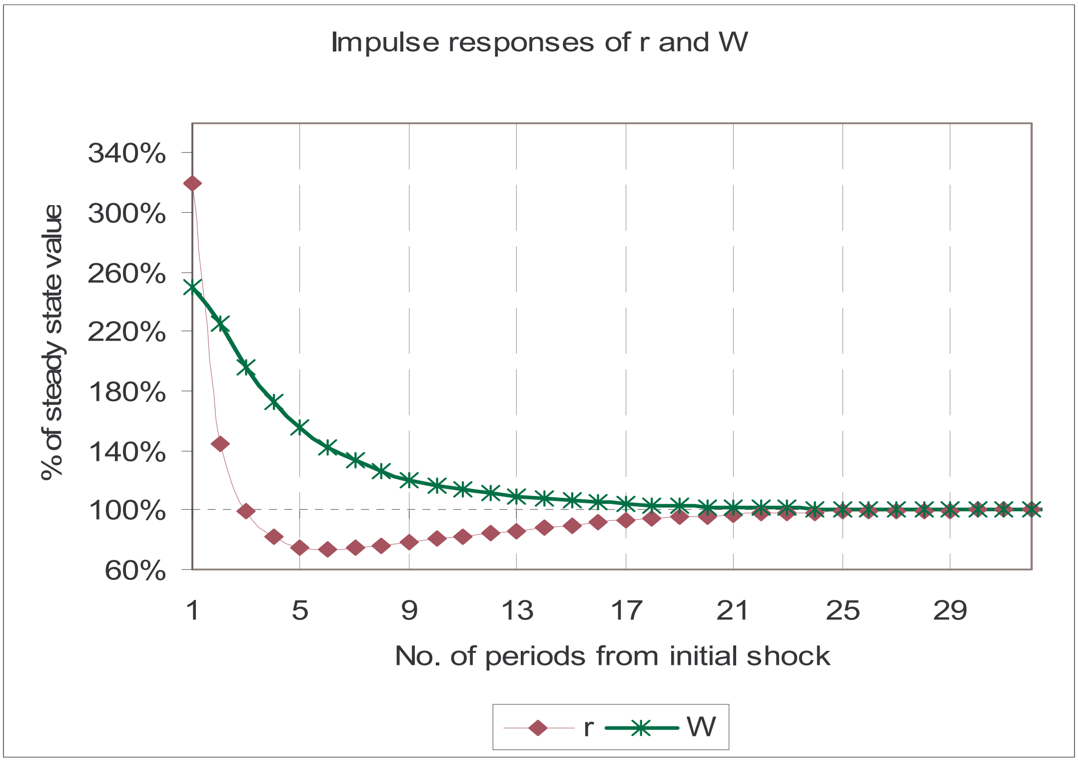
Business investment also goes up in the first period of the shock as can be seen from the sharp increase in business capital in the second period. In the steady state, business investment is just enough to replace the depreciated part of the business capital. The business capital hits the highest point at 207% of the steady state value in the third period.

The housing capital peaks later in the sixth period after the initial shock. Larger business capital accumulated makes it optimal to increase the holding of housing capital in the later periods. The consumption of non-housing goods peaks in the second period at 181% of the steady state value, before declining back to the steady state level.

The employment begins to decline in the second period and undershoots its steady state value in the fourth period after the initial shock. Higher interest income from larger holding of business capital makes it optimal for households to consume more leisure.

FIGURE 6.14

Interest rate and wage rate in the model with housing capital – positive shock

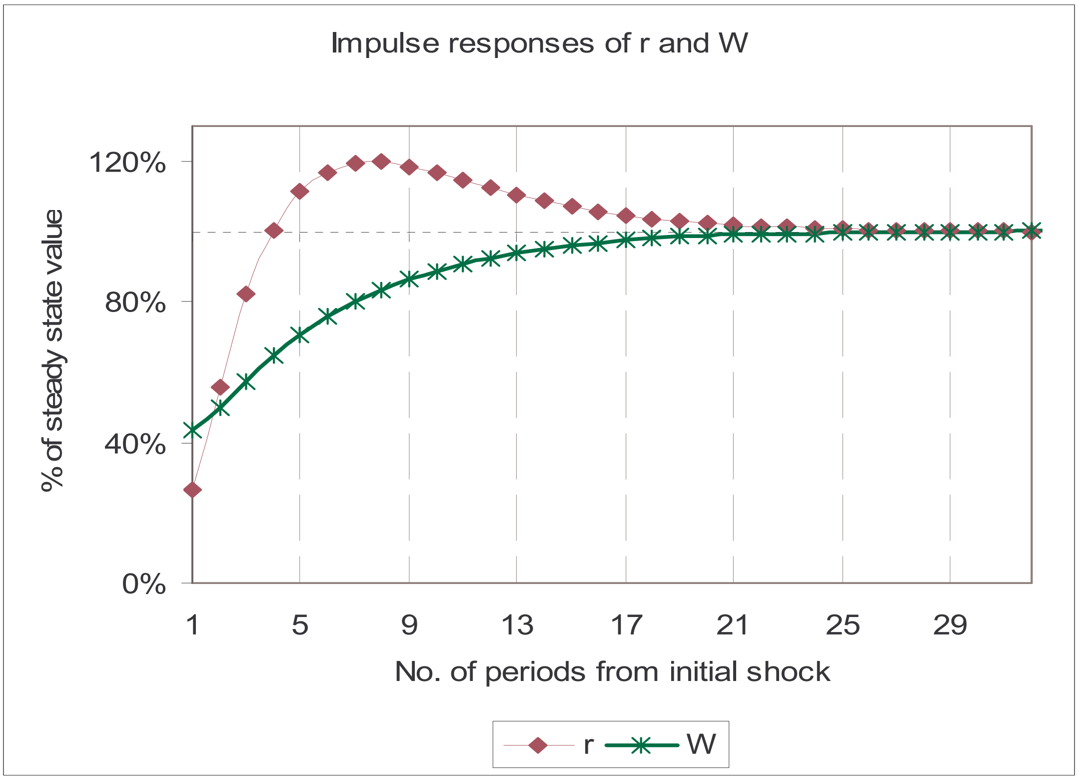


The interest rate and wage rate in the model economy in each period are computed as the marginal productivity of business capital and labor according to equation (4.8) and (4.9). The results are shown in Figure 6.14.

The interest rate jumps in the first period in response to the sudden increase in productivity. As households react to the positive shock by investing more in business capital, the interest rate drops sharply and undershoots its steady state value in the third period despite the persistent effect of the productivity shock. It bottoms in the sixth period before gradually rising back to the steady state value. The wage rate also jumps in the first period of the shock. It then gradually declines to the steady state value.

FIGURE 6.15

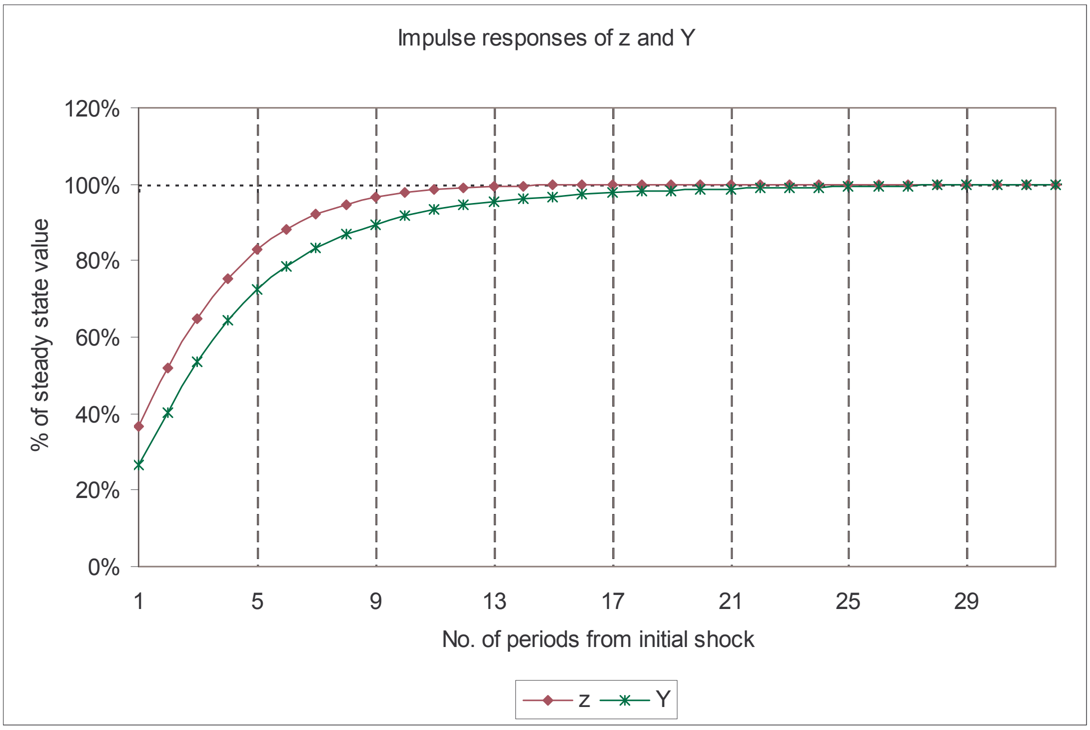
Interest rate and wage rate in the model with housing capital – negative shock

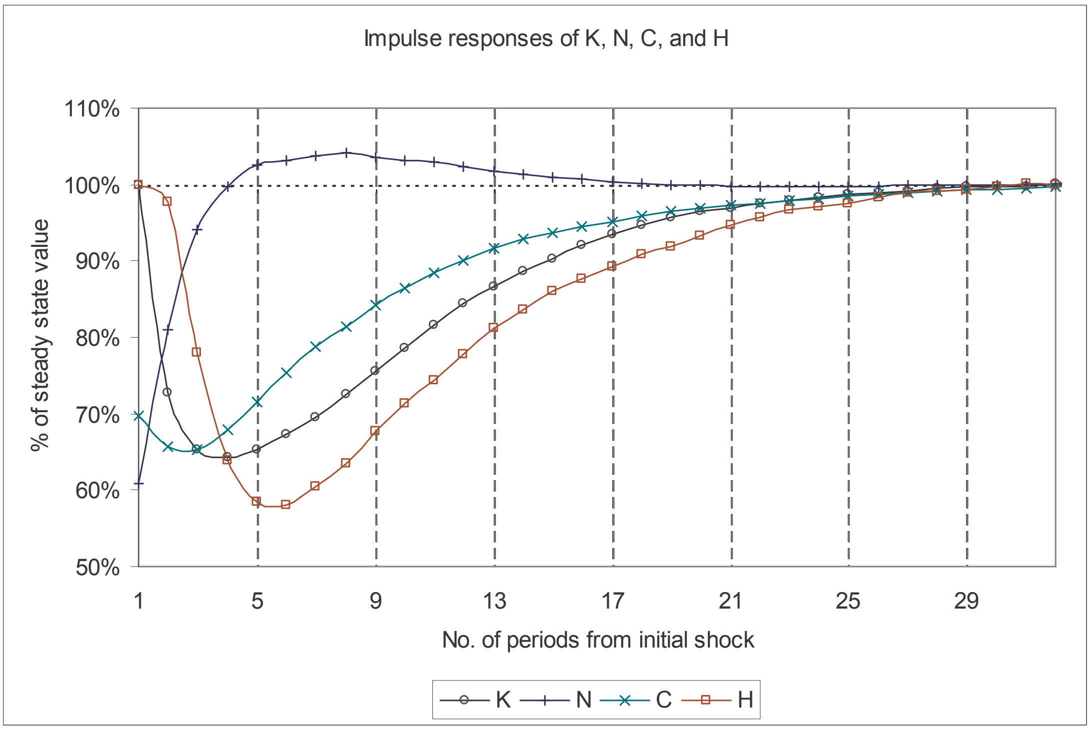


The impulse responses to the negative productivity shock are also examined, with the results shown in Figure 6.15 and 6.16. Basically, the results are mirror images of the case with positive shock.

FIGURE 6.16

Impulse responses in the model with housing capital – negative shock



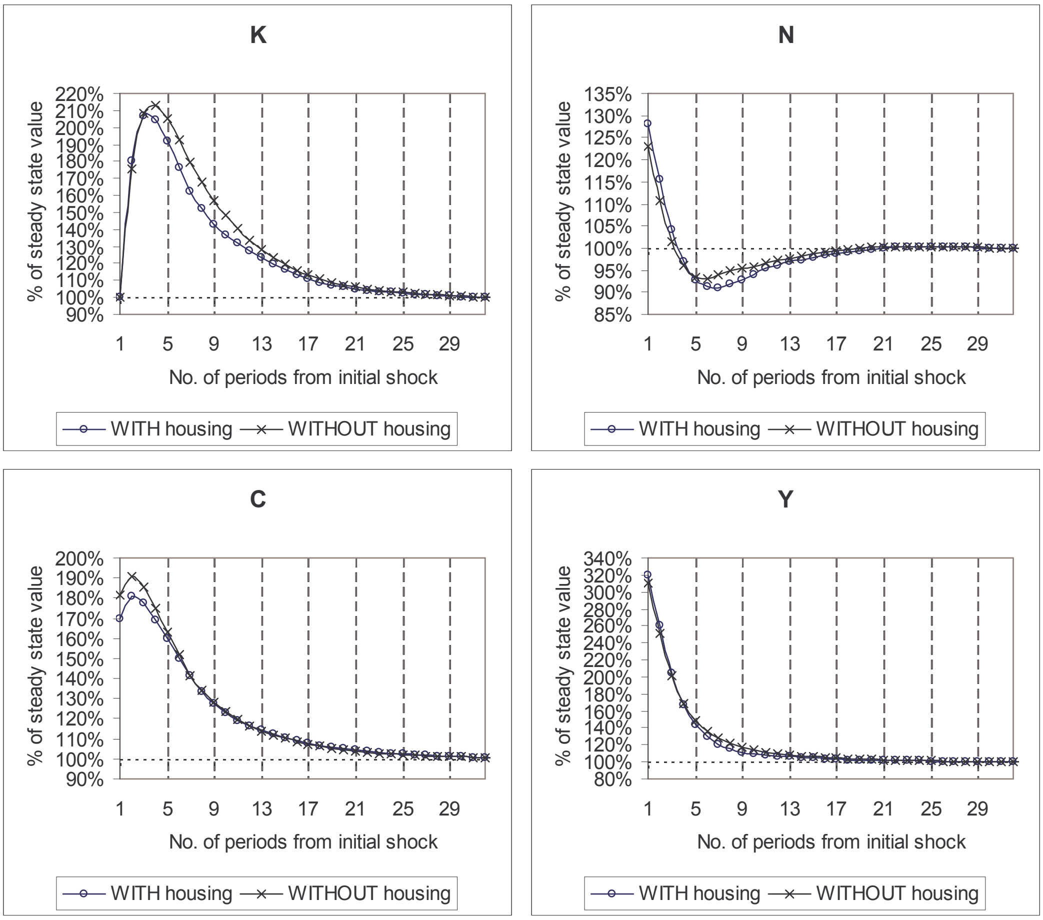


<u>6.4.3 Model without housing capital</u>

We now try to explore the change in impulse responses of each key variable when housing is not explicitly modeled. As in Section 6.2.3, the parameter θ, τ, and δ_h is set to one, zero, and zero, respectively. Figure 6.17 compares the impulse responses to positive productivity shock of K, N, C, and Y with and without housing capital.

FIGURE 6.17:

Impulse responses to positive shock – with and without housing capital



The impulse responses of K, N, C, and Y are qualitatively unchanged from the model with housing capital. For positive shock, business capital continues to grow after the third period to peak in the fourth period at 213% of the steady state value. The highest consumption (as a proportion of steady state value) still occurs in the second period but reaches 191%. Employment still undershoots its steady state value but to a lesser extent. The output tracks the case with housing capital quite closely.

Figure 6.18 shows the transition paths of interest rates and wage rates without housing capital. The results are also qualitatively similar to the base case model with housing capital. One of the reasons is that our model simplifies the production sectors such that housing capital is produced with the same technology as non-housing goods and business capital. Moreover, we assume that resources that are in the form of housing capital can be converted into non-housing goods and business capital. This simplification reduces the impact of including housing capital explicitly in the model.

FIGURE 6.18:

Interest rate and wage rate in the model with and without housing capital – positive shock

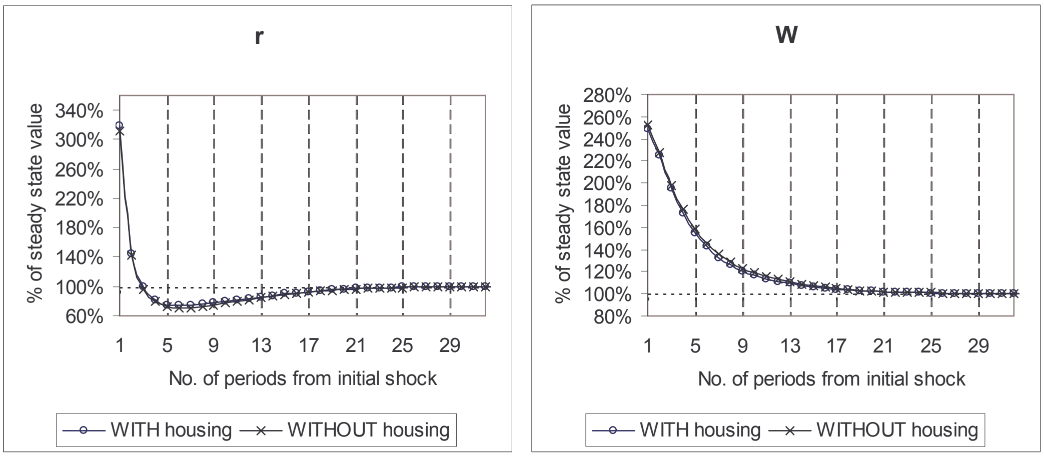


Figure 6.19 and 6.20 report the results in case of negative shock, which are basically just mirror images of the case of positive shock.

FIGURE 6.19

Impulse responses to negative shock – with and without housing capital

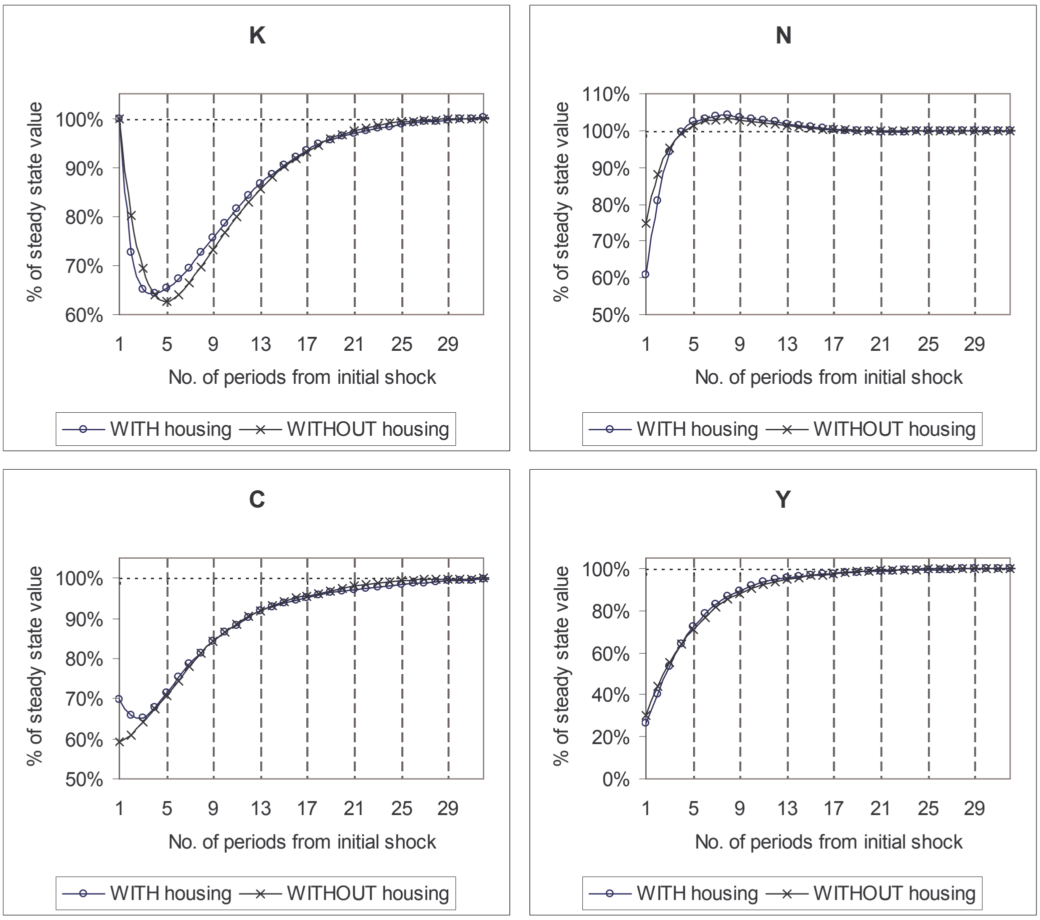


FIGURE 6.20

Interest rate and wage rate in the model with and without housing capital – negative shock