Why Does Household Investment Lead Business Investment Over the Business Cycle?

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Abstract

Household investment leads non-residential business fixed investment over the U.S. business cycle. Because real business cycle (RBC) theory has not been able to account for this observation, it represents a potent challenge to the view that transitory productivity disturbances are the main source of aggregate fluctuations. This paper reconciles RBC theory with the investment dynamics, by extending the traditional home production model to make household capital complementary with business capital and labor in market production. Empirical evidence suggesting that household capital is a complementary input in market production is also presented.

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1. Introduction

Economists have long recognized that investment in homes and consumer durables leads non-residential business fixed investment over the business cycle (*e.g.* Burns and Mitchell 1946). Indeed, in seven of the ten post-war recessions, including the two most recent, household investment reaches its peak and trough before business investment. While these dynamics are a major feature of the business cycle, real business cycle theory (RBC) has failed to account for them.[1] This failure challenges the view that transitory productivity disturbances are the main source of short run fluctuations. The objective of this paper is to reconcile RBC theory with the investment dynamics.

This reconciliation is accomplished by extending the traditional home production framework to make household capital complementary with labor and business capital in market production. Two ideas motivate this extension. First, household capital directly affects labor productivity. For example, analogous to the maintenance required to keep business capital in operating condition, workers must engage in rest, relaxation, and personal care to supply labor effectively. As a family grows, the size of its housing limits the quality of these activities. So, by increasing the size of its house, a household increases the productivity of its labor. The second idea underlying household capital as a complementary input to market production is that it is efficient for houses to be located near to business capital. An indication of this is that market production at a given location is limited by the supply of household capital at that location. The best example of this kind of complementarity is the factory town.[2]

This paper's extended home production model accounts for the investment dynamics by mitigating the incentive in the traditional model to substitute toward business capital after a positive productivity shock. In the traditional model, business capital produces market consumption and investment goods, while household

[1] The literature is replete with studies which account for the two kinds of investment being positively correlated, but nonetheless still imply business investment leads household investment. RBC studies which examine the behavior of home and business investment include Baxter (1996), Benhabib, Rogerson and Wright (1991), Campbell and Ludvigson (1998), Chang (2000), Davis and Heathcote (2005), Einarsson and Marquis (1997), Fisher (1994, 1997), Gomme, Kydland and Rupert (2000), Greenwood and Hercowitz (1991), Greenwood, Rogerson and Wright (1995), Hornstein and Praschnik (1997), McGrattan, Rogerson and Wright (1997), and Perli (1998). Edge (2000) and Li and Chang (2004) study the investment dynamics in monetary models.

[2] There are many historical examples of the factory town. One most famous example is Pullman, Illinois. This town was built by the industrialist George Pullman to house the workers employed in his railroad car factory.

capital only produces home consumption goods. This asymmetry in how many goods can be produced by each kind of capital provides a strong incentive to substitute away from household capital toward business capital after a productivity shock. Following a transitory productivity shock, investment in household capital initially falls as business investment rises, because the income effect which increases the demand for household capital is dominated by the substitution effect. With household capital a complementary input in market production, the production asymmetry is reversed, since household capital contributes to producing both market and home goods, while business capital produces only market goods. Accordingly, if household capital is complementary with labor and capital in market production, there is a strong incentive to build household capital before business capital.

Interest in the extended home production model hinges on the plausibility of including household capital in the market production function. If household capital is a complementary input in market production, then output per worker should be increasing in the quantity of household capital per worker. This prediction is used to test whether household capital appears in an aggregate production function estimated from US state-level data. The estimates indicate that workers, with the same education and working with the same business, government, and land capital, are more productive in states with more rooms per household. The elasticity of productivity with respect to rooms per household is economically and statistically significant. These findings suggest the proposed extension to the traditional home production model is worth investigating further.

The paper finds that plausible calibrations of home production models with household capital involved in market production reconcile RBC theory with the observed lead-lag pattern of household and business investment, while not diminishing their performance elsewhere. Moreover, the extended home production models account for co-movement between the two kinds of investment, and the higher volatility of household investment compared to business investment. In contrast, even with realistic gestation lags in business investment, traditional home production models consistently predict that business investment leads and is more volatile than household investment. The reduced form of the benchmark model can be derived from many underlying structures. This paper focuses on one such structure, but the main findings also follow from other models of household capital as a complementary input in market production.

Next I discuss empirical evidence which suggests household capital is a complementarity input to market production. This is followed by presentations of the benchmark model, the calibration, and the model's empirical implications. The penultimate section discusses alternative modelling approaches and the final section concludes.

2. The Effect of Household Capital on Labor Productivity

This section discusses previous empirical work and new findings which support the view that household capital is a complementary input in market production. The new empirical work, based on US state-level data, indicates that workers, with the same education and working with the same business, government, and land capital, are more productive in states with more residential rooms per household.

2.1. Previous Work

If the quality of rest, relaxation and personal care increase with household capital, say through the number of rooms in the home, then household capital increases labor productivity. Examples of such a connection include being able to get better rest because the baby is in another room, preparing a work presentation using a home office, even driving more comfortably to work. There is little empirical research addressing the connection, if any, between household capital and labor productivity.

Early work studied the effects of housing quality on labor productivity in developing countries. Burns and Grebler (1976) review several case studies of local housing initiatives in the developing world. Comparing the productivity of workers placed with their families in higher quality housing with those not so placed, they conclude that there are some gains in productivity and that the largest effects occur when workers are moved from very low levels of housing quality.

Hacker (1999) examines whether these effects extend to a more developed economy. Using Polish data, he studies whether residential crowding influences productivity. He finds that workers in the same industry, with the same education and working with the same capital-labor ratio and infrastructure, are more productive in regions with less residential crowding, as measured by average workers per room.

That there may be a relationship between home capital and labor productivity at low levels of housing is perhaps not surprising. However, the key question for this paper is whether there is a similar relationship in developed countries such as the US. The remainder of this section addresses this question.

2.2. Theory

The objective is to estimate a production function with US state-level data. Output in each state is assumed to equal state-specific total factor productivity multiplied by a Cobb-Douglas function which is identical across the states. Inputs into production include state stocks of business, household, government and land capital and the number and human capital of employed workers in the state. Variation across states in factor input use arises because relative prices vary across states. Firms in a given state are assumed to be price-takers in national factor markets.

This structure implies that for each state s the following relationship holds at each point in time

$$\ln y_s = \ln z_s + \alpha_h \ln h_s + \alpha_k \ln k_s + \alpha_g \ln g_s + \alpha_l \ln l_s + \alpha_e \ln e_s, \tag{2.1}$$

where y_s, h_s, k_s, g_s, l_s and e_s denote per worker output, household, business, government, land, and human capital for state s. The coefficients α_h, α_k, α_g, α_l and α_e are the factor input elasticities. The variable z_s is total factor productivity (TFP). TFP in a state is assumed to satisfy

$$z_s = A_s \exp(\boldsymbol{\beta}' \ln \mathbf{x}_s). \tag{2.2}$$

The variable A_s is a state-specific random disturbance consisting of idiosyncratic and aggregate parts. The variable $\mathbf{x}_s$, defined precisely below, is a vector of variables exogenous to the state which in addition to A_s determine TFP. For example, differences in industry composition are important for determining TFP at the state level. The term $\boldsymbol{\beta}$ is a vector of unknown coefficients.

Except for the household capital variable, the capital-labor ratios in (2.1) have familiar empirical counterparts. To measure household capital per worker, consider the following simple extension to the model described below in section 3. Households contain at least one adult and supply to the labor market at most two adults. Households grow or shrink stochastically over time by one child. Because labor needs to be regenerated, market effective labor is decreasing in the number of children and increasing in the number of rooms.[3] Economies of scale in

[3] Cudmore and Whalley (2003) consider the consequences of the regeneration idea for public finance.

regeneration arise because two adults can be regenerated with the same number of rooms as one adult. These assumptions imply that the household capital input to market production should be measured as the number of rooms multiplied by the average number of workers per household. Dividing this variable by the number of workers in a state yields rooms per household as the measure of h_s in (2.1).

2.3. Estimation

Substituting (2.2) into (2.1) yields

$$\ln y_s = \alpha_h \ln h_s + \alpha_k \ln k_s + \alpha_g \ln g_s + \alpha_l \ln l_s + \alpha_e \ln e_s + \boldsymbol{\beta}' \ln \mathbf{x}_s + \varepsilon_s, \qquad (2.3)$$

where $\varepsilon_s = \ln A_s$ is a random error term which is correlated across the states because of the aggregate productivity shock. Equation (2.3) is used to test the null hypothesis that household capital does not appear in the aggregate production function, $\alpha_h = 0$.

In general, this test is fraught with ambiguity. For example, richer households are often more productive than poorer households, and can afford more housing. As a result, equation (2.3) cannot be estimated by simple OLS. In particular, the housing and business capital variables are likely to be correlated with ε_s. To address this issue, I take an instrumental variables approach. Equation (2.3) is estimated by GMM using as instruments lagged household, business and government capital-worker ratios, lagged relative wages, plus two exogenous variables.

The lagged variables are suitable instruments if ε_s is serially uncorrelated or if the time lag is sufficiently long. At least one of these conditions is likely to be met. First, if $\mathbf{x}_s$ accounts for the persistent component of TFP, then ε_s should be serially uncorrelated. Second, if some high frequency serial correlation remains, then lengthening the time lag will mitigate its affect on the results.

The exogenous instruments are based on average annual costs in a state due to natural disasters. For these variables to be valid instruments they must only affect productivity through factor input use (*i.e.* factor prices) or the variables in $\mathbf{x}_s$. Using long term averages for the disaster costs should account for the restrictive building codes and insurance costs which make building in disaster-prone states relatively expensive.

2.4. Data

This paper focuses on cross-state instead of time series variation. There is no special reason for this other than the availability of data. In particular, the key number of rooms variable is only available in the decennial census. The base year of the analysis is 1997 and the lagged year is 1992. A time lag of five years should be sufficient to substantially mitigate any serial correlation in TFP unaccounted for by the variables included in $\mathbf{x}_s$. Detailed sources are listed in the Appendix.

The new variable studied in this paper is household capital per worker. As discussed above, this is measured as rooms per household. The rooms per household values in 1992 and 1997 are estimated from the nearest decennial census.[4] The number of rooms is calculated using all houses intended for year round habitation.

The other capital variables are constructed using data from several different sources. Business capital in each state is constructed by aggregating industry-specific capital stocks. A state's stock of capital in a particular industry is measured by its share of industry-wide capital, where the share is assumed to equal its share of national industry output. Government capital is accumulated past state and local government investment and land is just the square miles of the state. Human capital is measured as the number of workers with at least a high school degree. Using the number of workers with more than a high school education yields similar results. The number of workers is just employment in the state in one year.

The variables in $\mathbf{x}_s$ are intended to account for factors which lead to differences across states in industry composition. They include relative state wages (state average labor income divided by US average labor income), and the relative prices of equipment plus software investment goods and non-residential structures. If firms in each state are price-takers in national factor markets then these variables are exogenous and do not need to be instrumented for in the estimation. Dummy variables corresponding to the physical location of a state, measured by the northeast, midwest, south and west census regions, are also included in $\mathbf{x}_s$.

Output per worker is measured as real gross state product (GSP) per worker. Real gross state product includes imputed rents from owner-occupied housing. This fact alone means that GSP per worker is increasing in housing per worker. To eliminate this effect and emphasize the impact of household capital on market labor productivity, labor productivity is measured as net-of-real-estate GSP per worker.

The two exogenous variables used as instruments are log average annual real costs per worker due to floods and tornadoes. Averages are computed using data

[4] Another plausible measure of total housing input is residential square footage. This variable is in the American Housing Survey, but the codes needed to construct state-specific variables are suppressed in the publicly available data.

for the years 1955-1997 for floods and 1950-1994 for tornadoes. The averages are based on data from the National Weather Service.

2.5. Findings

Table 1 displays capital stock coefficients for five specifications of (2.3). Specification (1) excludes the rooms per household variable. In this case the business capital coefficient is .43 and highly significant. This estimate, derived only from cross-sectional information, is reasonably close to estimates derived from time series of factor income shares. No other capital per worker variable is significant in (1).[5] This turns out to be a robust feature of the data. Consequently these variables are dropped for the remainder of the analysis. Specification (2) is specification (1) without the other capital per worker variables. The coefficient on business capital in this case, .36, remains significant and close to estimates based on time series data.

Specification (3) adds the rooms per household variable to (2). The coefficient on rooms per household in this case, .16, is a little less than half the size of the business capital coefficient, which is unchanged from (2). The rooms-per-household coefficient is significantly different from zero at the 10% level. Its economic and statistical significance suggests household capital is a complementary input into market production.

The estimated coefficient on household capital in (3) might be spurious. For instance, it might be that small states, which are given equal weight with large states in the estimation, are driving the results.[6] In addition, the estimated coefficient might reflect the impact of an unmeasured fixed factor which makes states more productive and richer, increasing the demand for household capital. The remaining specifications in table 1 address these possibilities. First, they are based on a sample of states which exclude the 12 least populated states. The remaining 38 states include 94.6% of the US population. Second, they are used to assess the impact of including state per capita wealth in the estimated model.[7]

[5] Recall that the average wage in a state is included as an exogenous variable in all the specifications. This is probably a better measure of the quality of human capital in a state than the education variable used in specification (1). In all specifications the relative wage elasticity is economically and statistically significant.

[6] Weighting by the number of households or workers in a state yields similar results.

[7] I am grateful to Anna Paulson for providing me with the state wealth data. The 38 state sample includes the states for which reliable wealth data is available. Estimating specification (2) on this sample yields a statistically signficant coefficient on business capital whose magnitude

Specification (4) is (3) estimated on the smaller sample. In specification (4) the coefficient on the household capital variable is twice as large as it is in (3) and it is significant at the 1 percent level compared to the 10 percent level in (3). A possible explanation for these differences is that several variables used in the estimation, including rooms per household, are averages and the samples used to estimate these averages are smaller in the excluded states.[8] The coefficients on the capital-worker ratios are both larger than the corresponding coefficients in (3), but they are not statistically different from them. Specification (5) adds average wealth to (4). The estimated coefficient on average wealth is statistically insignificant. Therefore it seems unlikely that an unobserved fixed factor affecting wealth is driving the results.

Average wealth is one of many possible omitted variables. I have also investigated state terms-of-trade, residents per household, a dummy variable for the states identified by Holmes (1998) as "right-to-work" states, and the percent of state employment in a union. When added one-by-one to specifications (3) or (4) the coefficients on these variables are always statistically insignificant.

Overall, the findings point toward household capital appearing in the aggregate production function. This is a surprising result and suggests that the extended home production model is worth considering further.

3. The Model

The extended home production model developed in this section consists of households, firms and a government acting in a competitive equilibrium. The key departure from the traditional home production framework (see Greenwood, Rogerson and Wright 1995) is that household capital is complementary with other inputs in market production. In the model, complementarity arises from labor productivity being positively related to the stock of household capital.

3.1. Households

The representative household has preferences over a consumption good purchased from the market, c_{mt}, a consumption good produced in the home, c_{ht}, hours used in home production, n_{ht} and hours supplied to the labor market, n_{mt}. These

is close to that reported in table 1 for specifications (2) and (3).

[8] The household capital variable is also economically and statistically significant after weighting by the number of households or workers in a state in the estimation.

preferences are given by

$$\mathcal{E}_t \sum_{j=t}^{\infty} \beta^{j-t} \left[\ln c_{mj} + \psi \ln c_{hj} + \eta \ln \left(1 - n_{mj} - n_{hj}\right) \right], \tag{3.1}$$

where $\mathcal{E}_t$ is the mathematical expectations operator conditional on time t information and $\eta, \psi > 0$. One period of time corresponds to a quarter of a year. This specification of preferences reconciles the trend in the consumption price of household investment goods and the stable nominal share of expenditures on household investment goods. Assuming less or more substitution between home and market consumption would not be consistent with this evidence (see Fisher 1994, 1997 and Kydland 1995).

The household capital complementarity hypothesis is modelled by assuming that households supply *effective* hours, $\widetilde{n}_{mt}$, to the labor market, where effective hours are derived from inputs of market time and household capital. Specifically,

$$\widetilde{n}_{mt} \leq h_{nt}^{\mu} (z_t n_{mt})^{1-\mu}, \tag{3.2}$$

where z_t is the exogenous, stochastic and trend stationary level of the neutral technology, h_{nt} is the stock of household capital applied to producing effective hours supplied to the labor market, and $0 \leq \mu < 1$.

At each date t, the household faces the following budget constraint

$$c_{mt} + p_{mt} x_{mt} + p_{ht} x_{ht} \leq (1 - \tau_k) r_t k_t + (1 - \tau_n) w_t \widetilde{n}_{mt} + \delta_m \tau_k k_t + \xi_t. \tag{3.3}$$

Here p_{mt} and x_{mt} denote the price and quantity of the household's investment in business capital, p_{ht} and x_{ht} denote the price and quantity of its investment in household capital, k_t is the household's stock of business capital, r_t is the rental rate on that capital and w_t is the wage for effective hours worked. Business capital and effective market hours are taxed at the rates τ_k and τ_n, respectively. Consistent with the U.S. tax code, there is a depreciation allowance for capital taxation, $\delta_m \tau_k k_t$, where $0 < \delta_m < 1$ is the rate of depreciation on business capital. Since household capital contributes to effective market hours it is implicitly subject to the labor tax. Finally, ξ_t is a lump-sum transfer from the government.

Household capital projects take one period to complete so that the stock of household capital, h_t accumulates according to

$$h_{t+1} = (1 - \delta_h) h_t + x_{ht}, \tag{3.4}$$

where $0 < \delta_h < 1$ is the rate of depreciation on household capital. In addition to being an input into effective labor, household capital is an input in the production of home goods. Specifically,

$$c_{ht} \leq h_{ct}^{\phi} \left(z_t n_{ht} \right)^{1-\phi}, \tag{3.5}$$

where h_{ct} is the amount of household capital used to produce consumption goods in the home, and $0 < \phi < 1$.[9] Finally, in any given period the uses of household capital in the delivery of market hours and in producing home goods are subject to the availability of household capital in that period,

$$h_{nt} + h_{ct} \leq h_t. \tag{3.6}$$

Business capital is accumulated according to the technology introduced by Kydland and Prescott (1982). Specifically, capital projects require a flow of investment lasting J periods until they are completed. Let s_{jt} denote the number of projects j periods from completion at time t and let ω_j denote flow of investment in a project j periods from completion. Then, total investment in business capital at date t is

$$x_{mt} = \sum_{j=1}^{J} \omega_j s_{jt} \tag{3.7}$$

and projects evolve according to

$$s_{jt+1} \leq s_{j+1t}, \tag{3.8}$$

$j = 1, 2, \ldots, J-1$. Given this structure, business capital accumulates as follows

$$k_{t+1} = (1 - \delta_k) k_t + s_{1t}. \tag{3.9}$$

The problem of the representative household is: maximize (3.1) subject to (3.2)-(3.6) by choice of c_{mt}, c_{ht}, h_{t+1}, k_{t+1}, s_{1t+1}, s_{2t+1}, ..., s_{J-1t+1}, s_{Jt}, h_{nt}, h_{ct}, n_{mt} and n_{ht}.

[9] With the specification of preferences (3.1), productivity is additively separable in the reduced form utility function and so does not directly affect household decisions. It is included in (3.5) so the model exhibits balanced growth.

3.2. Firms

The representative firm produces consumption and investment goods with capital and effective labor services to maximize profits,

$$c_{mt} + p_{mt}x_{mt} + p_{ht}x_{ht} - r_t k_t - w_t \widetilde{n}_{mt},$$

where

$$c_{mt} + \frac{x_{mt}}{v_{mt}} + \frac{x_{ht}}{v_{ht}} \leq k_t^{\alpha} \widetilde{n}_{mt}^{1-\alpha} = y_t,$$

$v_{mt} = \gamma_m^t$ and $v_{ht} = \gamma_h^t$ and y_t is market output in consumption units.[10] The production function in the last expression simplifies the one estimated in section 2. The parameters $\gamma_m, \gamma_h \geq 1$ govern the rate at which business and household investment-specific technical change occurs. In the competitive equilibrium the investment good prices are given by $p_{mt} = 1/v_{mt}$ and $p_{ht} = 1/v_{ht}$, and the nominal ratios of consumption and the two kinds of investment to output are stationary random variables.

According to (3.2), effective market hours, $\widetilde{n}_{mt}$, depend on the level of the neutral technology, z_t. This technology grows at the gross rate $\gamma_z \geq 1$ on average, and is subject to exogenous disturbances:

$$z_t = \gamma_z^t \exp(\theta_t), \;\; \theta_t = \rho\theta_{t-1} + \varepsilon_t, \;\; \varepsilon_t \sim \mathbf{N}(0, \sigma^2).$$

3.3. Government

A government is included in the model to be consistent with the literature. Its only function in the model is to raise revenues and rebate these revenues lump-sum to households:

$$\xi_t = \tau_k r_t k_t + \tau_n w_t \widetilde{n}_{mt} - \delta_k \tau_k k_t.$$

4. Benchmark Parameters

The benchmark parameters are chosen by following the strategy outlined in Greenwood, Rogerson and Wright (1995). The findings' robustness to reasonable perturbations of the benchmark parameters is explored below. The data underlying the calibration is described in the appendix. Parameters governing preferences (β,

[10] For simplicity, I do not introduce notation to distinguish between the demand and supply of factor inputs or final goods.

ψ, η) home production (ϕ, δ_h), market production (α, δ_k, J, $\{\omega_i : i = 1, 2, ..., J\}$), productivity growth ($\gamma_z$, γ_h, γ_m, ρ, σ), taxes (τ_k, τ_n) and household capital's share in effective market labor (μ) need values. The four benchmark specifications involve assuming one- or four-quarter time-to-build of business capital, and whether or not household capital is a complementary input in market production. Conditional on the parameters underlying these cases, the remaining parameters are chosen consistently across the specifications.

4.1. Parameters in the Traditional Model

The one quarter time-to-build business investment technology uses $J = 1$ and $\omega_1 = 1$. The four quarter case is considered by Kydland and Prescott (1982) and Gomme, *et. al.* (2000). It involves setting $J = 4$ and $\omega_1 = \omega_2 = \omega_3 = \omega_4 = 0.25$. This case captures the fact, documented by Edge (2000), that business capital projects generally take longer than household capital projects to complete and is broadly consistent with the evidence presented by Koeva (2000).

The discount factor β is set so that the real interest rate averages 4 percent at an annual rate. The tax rates are the values used by Greenwood, *et. al.* (1995), $\tau_n = 0.25$ and $\tau_k = 0.7$. The value for the labor tax is close to values used elsewhere in the RBC literature. Greenwood, *et. al.* (1995) use a large value of the capital tax rate. They argue it is a reasonable value because it is the mean of reported values in Feldstein, Dicks-Mireaux and Poterba (1983) and because it captures "all forms of government regulation, interference, or any other institutional disincentive to invest in business capital, not only direct taxation (p.165)." Following Fisher (1995) and Greenwood, Hercowitz and Krusell (1997) the growth rates of the investment-specific technologies, γ_m and γ_h, are chosen to match the real investment good prices' mean rates of decline. This procedure yields $\gamma_m = 1.0024$ and $\gamma_h = 1.003$. The parameters for the technology shock process are chosen to be consistent with the literature: $\rho = 0.95$ and σ is set so that the innovation of $\exp((1-\alpha)(1-\mu)\theta_t)$ has a standard deviation of 0.00763.[11]

Conditional on all the other parameters, ψ, η, ϕ, δ_h, α, δ_m and γ_z, are chosen to match seven calibration targets: averages of the time devoted to market and non-market work, nominal ratios of capital and investment to output, and

[11] Solow residuals derived from the models in this paper are not identical to ones from a traditional home production model. In principle this suggests an adjustment to the assumed technology process is in order. However, since capital does not vary much in the model over short horizons, adjusting for this has little quantitative impact.

growth rate of real per-capita consumption excluding housing services.[12] The first two target values are based on time use studies, including the ones discussed by Greenwood, *et. al.* (1995) and the more recent 2003-2004 American Time Use Survey conducted by the Bureau of Labor Statistics. The targets are 1/3 of the time endowment is devoted to market work and 1/4 to non-market work. The other five targets are based on recently published capital stock, investment, consumption and output data. Business capital is measured as private non-residential fixed capital, and household capital is measured to include private residential capital and consumer durables. The two investment series are measured analogously. Consumption is measured as non-durables and services, excluding housing services, and output is measured as GDP less consumption of housing services. Over the sample period 1948-2004, the average nominal business and household capital-output ratios are 4.66 and 6.15, the corresponding investment shares are 0.12 and 0.16, and average real per-capita consumption growth is 0.45 per cent. The implied depreciation rates and capital's share are the same in the four benchmark specifications: $\delta_m = 0.019$, $\delta_h = 0.017$ and $\alpha = 0.28$. The remaining parameters are $(\psi, \eta, \phi, \gamma_z) = (0.56, 0.76, 0.19, 1.0026)$ in the specifications with household capital complementarity and $(\psi, \eta, \phi, \gamma_z) = (0.81, 0.94, 0.31, 1.0036)$ in the specifications without it.

4.2. Household Capital's Share of Effective Labor, μ

The last parameter to identify is the share of household capital in delivering effective market hours, μ. The case corresponding to the traditional home production model is $\mu = 0$. For the case incorporating the new complementarity, μ is selected to demonstrate the potential of the model to account for the investment dynamics. Specifically, μ is chosen by minimizing a measure of the distance between a given version of the model and empirical dynamic correlations between detrended log household and business investment. The estimated value of μ is compared to values obtained from other sources below.

Let the column vector $\Psi(\mu)$ denote the mapping from μ to the model correlations between x_{ht+j} and x_{mt}, $j = -2, -1, 0, 1, 2$, and let $\widehat{\Psi}$ denote the correspond-

[12] The log of real per-capita consumption growth in the model is given by $\ln \gamma_z + (\alpha \ln \gamma_m + \mu(1-\alpha) \ln \gamma_h)/[(1-\alpha)(1-\mu)]$. Notice that this depends on the neutral technology and *both* of the investment-specific technologies.

ing empirical estimates. The metric used to estimate μ is $\mathcal{L}(\mu)$, where

$$\mathcal{L}(\mu) = \left[\Psi(\mu) - \widehat{\Psi}\right]' V^{-1} \left[\Psi(\mu) - \widehat{\Psi}\right] \tag{4.1}$$

and V is a diagonal matrix with the sample variances of the $\widehat{\Psi}$ along the diagonal. These variances underlie confidence intervals for the dynamic correlations displayed below. Let

$$J = \mathcal{L}(\hat{\mu}),$$

where $\hat{\mu}$ minimizes $\mathcal{L}(\mu)$. Such values $\hat{\mu}$ are my estimates of μ. By the choice of V, $\hat{\mu}$ is chosen so that $\Psi(\hat{\mu})$ lies as much as possible inside the confidence intervals for the dynamic correlations. Under the null hypothesis that the model is true, and ignoring sampling uncertainty in the other parameters, the distribution of J can be estimated using bootstrap methods.[13] This distribution is used below to evaluate the fit of the model under different assumptions.

The estimates of μ obtained for the one-quarter and four-quarter time-to-build versions of the model with household capital complementarity both equal 0.19. The reduced form share on household capital is $\mu(1-\alpha) = 0.14$. One way to assess the empirical plausibility of this share is to compare its value to the estimated coefficients on rooms per household in table 1. The value 0.14 is easily within the 95% confidence interval of the estimated coefficient on rooms per household in specification (3), and is just outside the corresponding confidence interval for specification (4). Another gauge of plausibility involves an estimate in Saks' (2005). She finds that the response of output to a permanent increase in productivity is 18 percent smaller in metropolitan areas where the housing market is highly constrained by regulation compared to a less constrained control group. In the model, suppose the stocks of household capital devoted to home and market production are held constant. The impact of a permanent increase in the neutral technology, z_t, in this case is to raise output by μ percent less than when household capital is free to adjust. So, based on Saks' (2005) estimate, $\mu = 0.19$ seems empirically plausible.

[13] Specifically, a vector-autoregression in four lags of the logs of output and the two kinds of investment estimated using the sample period 1948:1 to 2004:4 is used as the data generating process to generate 10,000 artificial samples. For each of these samples, the J-statistic based on the difference between the dynamic correlations computed using the artificial sample and the point estimates from the empirical sample is constructed. This sample of 10,000 J-statistics is used to construct $p-$values.

5. Quantitative Implications of the Theory

This section shows that home production models in which household capital is a complementary input into market production reconcile RBC theory with the lead-lag pattern, co-movement and relative volatility of household and business investment. Realistic gestation lags in business investment improve the performance of the model with complementarity. However, the model with realistic gestation lags and without complementarities predicts that business investment leads and is more volatile than household investment. These findings are based on the benchmark parameters. The second part of this section discusses their robustness to reasonable perturbations of the benchmark calibration.

5.1. Benchmark Specifications

The main findings for the benchmark specifications are displayed in Table 2 and Figures 1-3. Figures 1-3 are a graphical presentation of the information in Table 2's Panel B. All statistics are based on data described in the appendix which has first been logged and detrended with the Hodrick-Prescott filter.

The first main point is that, according to Table 2's Panel A, there is little to choose between the four specifications in terms of a traditional list of statistics. The properties of home production models along these dimensions have been discussed at length elsewhere, for example in Greenwood, *et. al.* (1995). So, the focus here is on the behavior of household and business investment, where clear differences between the specifications emerge.

Table 2's Panel B and Figures 1-3 confirm that the specifications without complementarity fail to account for the investment dynamics.[14] In the figures the vertical lines with hash marks indicate plus and minus two standard deviation error bands about the point estimates for the indicated correlations and the dots show the model's predictions. Consider the one-quarter time-to-build case. In the data, household and business investment co-move positively: the contemporaneous correlation is statistically significant and equal to 0.38. But, the model predicts household investment and business investment are negatively correlated contemporaneously, with a point estimate equal to -0.53. The one-quarter time-to-build

[14] Except for the relative price trends, the one quarter time-to-build model without complementarity has the same structure as 'Model 1' in Greenwood, *et. al.* (1995) and Greenwood and Hercowitz (1991). Absent the relative price trends, the four quarter time-to-build model corresponds to the model focused on by Gomme, *et. al.* (2000).

version of the model also predicts that household investment lags business investment, contrary to the U.S. data.[15] These dynamics are evident in the relatively large positive correlations of household investment with past business investment, the relatively large positive correlations of household investment with past output and the relatively large positive correlations of business investment with future output. The final major failure of this model concerns the relative volatility of household and business investment. Without household capital complementarity, the one-quarter time-to-build specification predicts that business investment is much more volatile than household investment: the ratio of the standard deviation of household investment to the one for business investment is 0.62. In the data it is 1.3 and significantly greater than unity.

The co-movement and lag-lead pattern of household and business investment in traditional home production models were first explained by Greenwood and Hercowitz (1991). The dynamics follow from a basic asymmetry in these models that business capital is useful for producing more types of good than household capital. After a positive productivity shock there is a strong incentive to move resources out of the home to build up business capital and only later is household capital accumulated.

Increasing the time-to-build of business capital relative to household capital has the potential to move traditional home production models much closer to the data. Gomme, *et. al.* (2001) describe intuition for why. With four-quarter time-to-build, only a fraction of the total resources for business investment are needed in the period of a positive productivity shock since the effect of the shock on business investment is spread over the time it takes to complete a project. Compared to a model with one-quarter time-to-build, this makes it more costly to quickly install new business capital and lowers the opportunity cost of immediate investment in household capital. Consequently, if household capital is not subject to the same gestation lags, there is an increased incentive to accumulate it over business capital.

Ultimately the impact of this mechanism depends on how much it is offset by the competing forces described by Greenwood and Hercowitz (1991). According to Table 2's Panel B, the forces pushing the model in the direction of negative co-movement and a counterfactual lead-lag pattern are too strong to be overcome by increasing the time-to-build for business capital. The contemporaneous correlation between the two investment goods does rise to 0.09, but it is still significantly

[15] Formally, for variable x_t to lag (lead) variable y_t, the peak correlation of x_{t+j} with y_t would be for a positive (negative) value of j.

lower than the point estimate, and the counterfactual lead-lag pattern remains. Increasing the time-to-build of business capital has no impact on relative volatility. So, time-to-build *per se* does not reconcile RBC theory with the investment dynamics.[16]

In contrast, including household capital as a complementary input in market production has a dramatic favorable impact. With complementarity, not only is there an effect encouraging positive co-movement, there is also an effect which encourages agents to build up household capital before business capital. The former arises because of the complementarity between the two kinds of capital in market production. The latter arises because with complementarity, household capital is useful for producing more goods than business capital. Of course the magnitude of these effects depends on the calibration, in particular the share of household capital in market production.

Figure 4, which displays the theoretical responses of household (dashed lines) and business investment (solid lines) to positive innovations in productivity, illustrates that these effects are strong. Without complementarity and with one-quarter time-to-build (first column and row) the two investments move in opposite directions in the period of a shock. Raising the time-to-build for business capital to four-quarters (first column, second row) delivers a modest improvement by encouraging some positive co-movement in the early periods, but the later negative co-movement essentially offsets this. When household capital complementarity is added to the one-quarter time-to-build model (second column, first row), household investment responds positively in the period of the shock and business investment responds with a lag. Increasing the time-to-build of business capital under complementarity reinforces the tendency for business capital to lag household capital (second row and column). In this case there is a much slower build up of business investment while household capital continues to respond sharply in the periods after the shock.

These responses have a substantial impact on the statistics in Table 2's Panel B, moving the model a long way toward the data. First, even in the one-quarter time-to-build case, household investment co-moves positively with business investment. The contemporaneous correlation between these variables is 0.25 and

[16] The statistics reported by Gomme, *et. al.* (2001) are marginally more favorable to the four-quarter time-to-build model. Their results are based on a similar calibration procedure, but with calibration targets for the capital-output ratios derived from data which has been revised. However, as discussed below, even with their calibration targets, the four-quarter time-to-build model continues to predict counterfactual investment dynamics.

within two standard deviations of the point estimate from the data.

Second, regardless of the time-to-build of business capital, the correlations of household investment with future business investment are larger than the correlations with contemporaneous and lagged business investment. That is, household investment clearly leads business investment. While qualitatively successful, the one-quarter model does over predict the one period lead of household over business investment. Here, consistent with the responses in Figure 4, increasing the time-to-build of business capital clearly improves the quantitative pattern of the investment dynamics.

The J-statistics with p-values in square brackets in Table 2's Panel C provide a formal statistical assessment of the dramatic improvement in the investment dynamics achieved with household capital complementarity. The models without complementarity are strongly rejected by the data. The model with complementarity and one-quarter time-to-build is not rejected, consistent with the huge reduction in the J-statistic from the comparable case without complementarity, from 426 to 27.8. Once time-to-build of business capital is increased, the J-statistic falls further to 5.51 so that this model also is not rejected.

Household capital complementarity leads to two further improvements. One is that household investment is more volatile than business investment, as indicated in the last row of Table 2's Panel B. This pattern of volatility in traditional home production models has been almost as hard to achieve in traditional models as the lead-lag pattern. The second improvement is that the dynamic correlations of the two kinds of investment with output are much closer to the data. Now the lead correlations of household investment with output are larger than the corresponding lag correlations, and the lag correlations for business investment with output are larger than the corresponding lead correlations.

In summary, introducing household capital complementarity into traditional home production models leads to a dramatic improvement in their empirical performance. It overcomes the three main drawbacks of traditional models in terms of their predictions for household and business investment: their lead-lag pattern, co-movement and relative volatility.

5.2. Robustness of the Benchmark Findings

This section explores the robustness of the four-quarter time-to-build model's implications for investment. There are two main results. First, the lead-lag and relative volatility findings hold for a large range of values for μ, but contemporaneous co-movement is less robust. Second, the investment dynamics are not very sensitive to other perturbations of the benchmark calibration.

Figure 5 illustrates the impact of μ on the investment dynamics. Plot A displays correlations of household investment at $t+j$ with business investment at t, for $j = -2, 0, 2$, and Plot B shows relative volatility. These statistics are based on re-calibrating the model for each value of μ. The vertical lines mark μ's point estimate. Plot A reveals that household investment leads business investment for $\mu > 0.13$. The contemporaneous correlation is close to its point estimate for $0.05 < \mu < 0.20$, but it falls off sharply and becomes negative for values of μ exceeding its point estimate. As μ gets larger, household capital becomes more important in market production, which increases the incentive to divert resources toward building home capital. Plot B shows that household investment volatility exceeds that of business investment for $\mu > 0.11$.

Other perturbations of the benchmark calibration to be considered include alternative calibration targets for the capital-output ratios and the investment-specific technologies' growth rates, as well as a different business investment technology. When choosing targets for the capital-output ratios, previous studies use older data that has been subsequently revised. The more recent data used in this paper incorporates lower estimated depreciation rates so that capital stock estimates are revised upward.[17] How important are these revisions to the main findings? To address this question, the model is re-calibrated to the minimum and maximum values of the two capital-output ratios in the sample.[18] The minimum ratios are similar to those considered before in the literature. In both cases, the model continues to exhibit strongly counterfactual investment dynamics when $\mu = 0$. When μ is re-estimated, the model's predictions for the investment dynamics are close to the benchmark case. The estimated values of μ do not change much: $\hat{\mu} = 0.17$ with the smaller ratios and $\hat{\mu} = 0.22$ with the larger ones. So, the main findings do not depend on the benchmark capital-output ratios.

Previous studies have abstracted from the investment price trends. How important are these trends for the findings? Suppose the investment technology growth rates are set to zero. Re-calibrating this model according to the rest of the benchmark calibration yields results similar to the benchmark case when μ is estimated. With $\mu = 0$ the model corresponds to the one studied by Gomme, *et. al.* (2000), except that it is calibrated with more recent data. This model

[17] See Fisher (2001) for a more detailed discussion of the revised data.

[18] The minimum ratios for household and business capital are 5.49 and 3.99 and the corresponding maximum ratios are 6.97 and 5.80.

yields co-movement and a slight lead of household over business investment, but business investment is much more volatile than household investment, and the magnitudes of the dynamic correlations are still quite different from their empirical values (J-statistic is 92.3, p-value is 0.003.)[19] These findings indicate that the price trends make it harder for RBC models to account for the correlations, but easier to account for relative volatility.

The final robustness check is to consider a different business investment technology. Is the poor performance of the benchmark model without household capital complementarity due to an improper specification of time-to-build? Suppose there is a planning phase component to time-to-build. This is well motivated on empirical grounds, and it is possible that adding a mechanism encouraging business investment to lag household investment would improve the performance of the model. A planning phase is modelled by setting $J = 4$, $\omega_1 = 0.01$, and $\omega_2 = \omega_3 = \omega_4 = 0.33$. Re-calibrating this model with $\mu = 0$ implies household investment leads business investment, but it also implies a large negative contemporaneous correlation. So this model is strongly rejected. Time-to-plan encourages a surge in household investment in advance of a build-up of business investment. However, as soon as the resource flow into the newly initiated market projects rises, there is a swift cut-back in household investment. When μ is estimated, $\hat{\mu} = 0.20$, and the results are similar to the benchmark.

6. Other Modelling Approaches

The reduced form of the extended home production model can be derived from many underlying structures. This paper focuses on one such structure, but the main findings also follow from other models of how household capital is made a complementary input in market production. This section briefly considers several other approaches to modelling this hypothesis and argues that the main findings continue to hold. For simplicity the focus is versions of the model with one-quarter time-to-build for business capital.

The complementary nature of household capital is motivated in the introduction by two ideas. Consider first the idea that labor must be regenerated to be effective. Under this interpretation, there are three natural alternatives to (3.2). The first concerns the rival uses for household capital in the benchmark model. A natural alternative to the rival uses assumption, is to assume joint production

[19] The results are similar if, in addition to fixing the investment technologies, Gomme, *et. al.*'s (2001) calibration targets for the capital-output ratios are used as well.

with household capital, $h_{nt} = h_{ct} = h_t$. Redoing the analysis of section 5 under joint production yields similar results.

Second, are the results robust to assuming that home workers need to be regenerated? Suppose the model with joint production includes the additional assumption that home production depends on effective home hours, where these effective hours are produced using time and household capital as inputs in a Cobb-Douglas production function. Then, it is easy to confirm that, for any value of the Cobb-Douglas share parameter, the only impact of including effective home hours is to change the calibrated values of the parameters ϕ, ψ and η. The reduced form of this model is identical to the calibrated benchmark and so the two models have identical predictions.

Third, are the results robust to including leisure in the production function for effective hours? It is certainly plausible that leisure has a role to play in generating effective market hours. Suppose, then, that leisure is added as an input into producing effective market hours, thereby adding one parameter to the model. Next, suppose this new parameter is identified by choosing it along with μ when minimizing the right hand side of (4.1). As with the other alternative specifications, this version of the model yields results similar to the benchmark. The only substantial difference is to reduce the volatility of consumption.

The second idea motivating the complementary nature of household capital is that it is efficient for household capital and business capital to be located near to each other – production at a given location is limited by the supply of housing at that location. A simple way to model this idea is to suppose, instead of a production function for effective market hours, that the total supply of labor is constrained by the quantity of household capital. Are the results sensitive to taking this alternative approach? Fisher (2006) describes a model in which the co-location idea is captured by assuming $\mu = 0$ and

$$n_{mt} + n_{ht} \leq \zeta_t h_t^{\kappa}, \tag{6.1}$$

where ζ_t is an exogenous term to guarantee balanced growth, and $\kappa \in (0, 1]$. Fisher (2006) describes how this model has a reduced form which is similar to the benchmark model. As a result this model yields results that are quite close to those of the benchmark.

7. Conclusion

This paper reconciles RBC theory with the lead-lag pattern, co-movement and relative volatility of household and business investment. That household capital is assumed to be a complementary input with business capital and labor in market production contributes most to this finding. In contrast, differences in gestation and planning lags between business and household investment alone do not account for investment dynamics' key features.

The paper also presents new evidence that household capital is a complementary input in market production. Although more work needs to be done before drawing definitive conclusions, the findings do suggest the extended home production model is worth investigating further. Since the empirical findings suggest that the traditional aggregate production is misspecified, other research which builds on the aggregate production function may need to be reconsidered as well.

Appendix

1. Data for Production Function Estimation

The data were obtained from the Haver databases USNA, GSP, CAPSTOCK, BEAEMPL, GOVFINR, and USPOP, IPUMS 1990 and 2000 1% Samples, the Census State and Metropolitan Area Data Book, the U.S. Statistical Abstract, the Survey of Income and Program Participation, and the National Weather service web site, http://www.spc.noaa.gov.

The sources by variable are as follows. State productivity is real GSP divided by employment and multiplied by the terms of trade. The terms-of-trade is the ratio of the state to GDP deflators, all from Haver. Rooms per household is from IPUMS. Private business capital per worker is calculated using data from Haver on SIC 1-digit industry capital stocks, NIPA gross output, and employment. Government capital is accumulated state and local government investment from Haver. For the accumulation, the depreciation rate for government capital in Haver is used each year. Land area of the states is from the U.S. Statistical Abstract. Wealth is average real household wealth from SIPP provided to me by Anna Paulson. Relative wages are constructed by dividing average labor income in a state by average US labor income using data from the Census State and Metropolitan Area Data Book. Relative investment good prices are derived by taking ratios of state-specific deflators and the GDP deflator. The state-specific deflators are chain weighted aggregates of the NIPA deflators for equipment and structures in Haver. The shares used for the chain-weighting are derived from state shares of industry output and industry-specific investment in equipment and investment, all from the NIPA accounts in Haver. The flood and tornado variable are real damages per worker for the years 1955-1997 and 1950-1994 from the National Weather Service website.

2. Data for the Calibration and Business Cycle Statistics

Most of this data is from the Haver Analytics database. The capital stock data is from the May 2004 and September 2005 issues of Survey of Current Business. All real series are in chained 2000 dollars. Except where noted, the original source for the series is the Bureau of Economic Analysis.

The data counterparts to the model variables are as follows: output is GDP less consumption of housing services, consumption is the sum of non-durables and services consumption less housing services, business investment is nonresidential fixed investment, household investment is the sum of residential fixed investment and durables consumption expenditures, total investment is the sum of household and business investment, hours is private hours on nonfarm payrolls. The capital stock series are the obvious counterparts to the investment series. The appropriate chain-weighting procedure was used when adding or subtracting a series from another.

The mnemonics of the series taken from the Haver Analytics database are in parenthesis after a description of the series as follows: gross domestic product (nominal – GDP, real – GDPH), nonresidential fixed investment (FN, FNH), residential fixed investment (FR, FRH), consumption of non-durables (CN, CNH), consumption of services (CS, CSH), consumer durable expenditures (CD, CDH), consumption of housing services (CSR, CSRH), private business hours (LXBH). The civilian non-institutional population over the age of sixteen is used for convert variables into per capita terms (LN16N). The Bureau of Labor Statistics is the primary source for the last two variables.

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Table 1. Estimated Factor Input Elasticities

Variable	Specification (1)	(2)	(3)	(4)	(5)
Capital Variable					
Household			.16*	.33**	.32**
			(.09)	(.09)	(.09)
Business	.43**	.36**	.36**	.45**	.45**
	(.06)	(.03)	(.03)	(.05)	(.05)
Government	-.08				
	(.09)				
Human	-.09				
	(.08)				
Land	.01				
	(.01)				
Wealth					.01
					(.02)
P-value of Hansen's J-statistic	.27	.09	.11	.23	.25
Adjusted R^2	.94	.95	.95	.93	.93
Number of Observations	50	50	50	38	38
Degrees of Freedom	39	42	41	29	28

Notes:

a. The specifications also include as explanatory variables the regional dummy variables and the relative price variables described in the text.

b. The lags of the included business, household and government capital variables, lagged relative wages and the natural disaster variables are the instrumental variables in all cases.

c. Robust standard errors are indicated in parenthesis below the coefficients' point estimates.

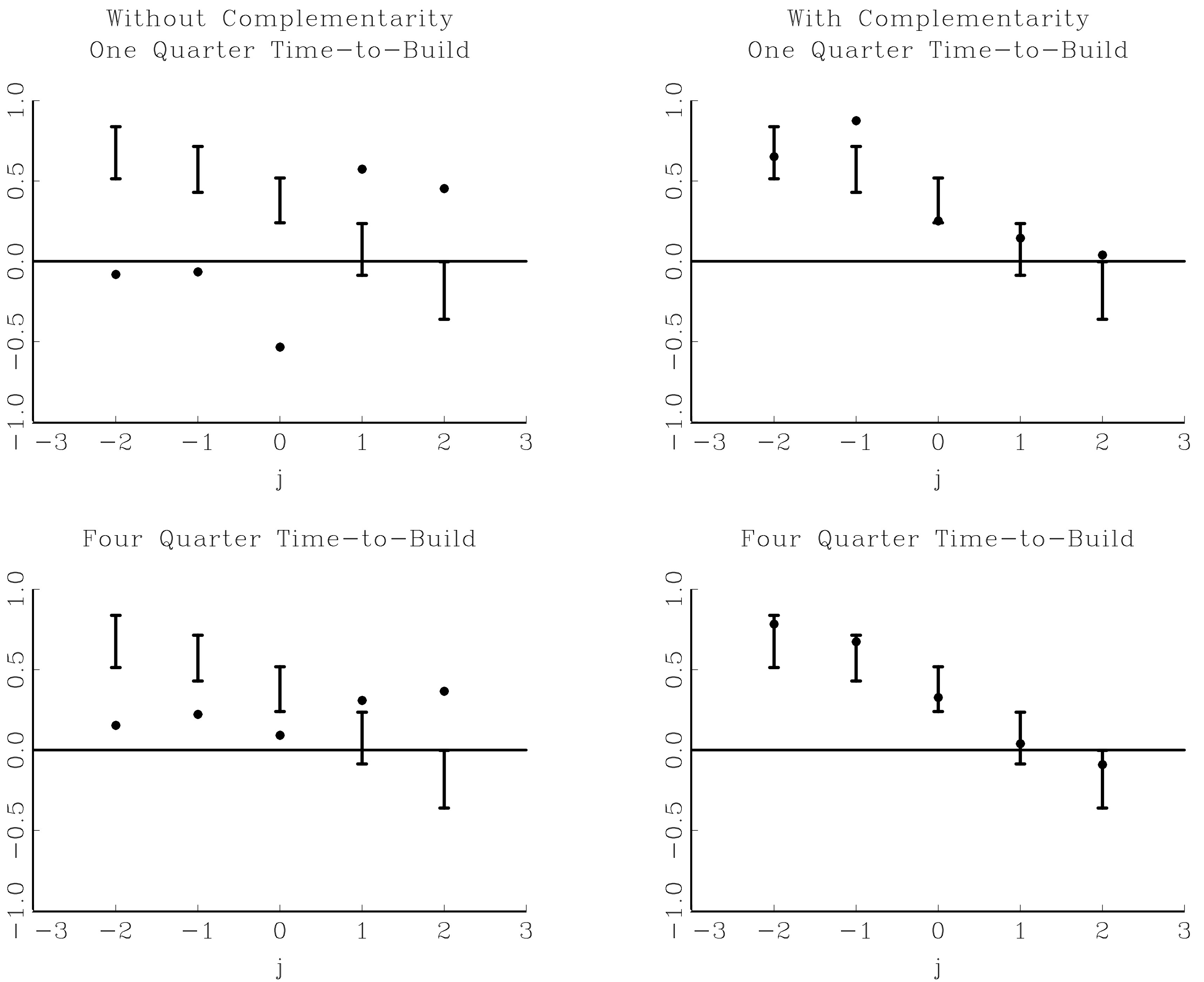
d. An asterisk denotes statistical significance at the 10 percent level and two asterisks denote significance at the 1 percent level.

Table 2: Properties of the Four Benchmark Specifications[c]

Statistic[a]	U.S Data[b]	One Quarter Time-to-build: With Complementarity	One Quarter Time-to-build: Without Complementarity	Four Quarter Time-to-build: With Complementarity	Four Quarter Time-to-build: Without Complementarity
		Panel A: Basic Statistics			
σ_y	1.87 (0.15)	1.38	1.56	1.35	1.41
σ_{n_m}/σ_y	0.80 (0.04)	0.43	0.44	0.44	0.43
σ_c/σ_y	0.52 (0.03)	0.37	0.36	0.37	0.35
σ_x/σ_y	2.56 (0.15)	2.76	2.79	2.74	2.73
$\rho(n_{mt}, y_t)$	0.83 (0.03)	0.99	0.99	0.99	0.99
$\rho(c_t, y_t)$	0.77 (0.04)	0.97	0.97	0.96	0.97
$\rho(x_t, y_t)$	0.76 (0.07)	0.99	0.99	0.99	0.99
		Panel B: Investment Dynamics			
$\rho(x_{ht-2}, x_{mt})$	0.68 (0.08)	0.65	-0.08	0.78	0.15
$\rho(x_{ht}, x_{mt})$	0.38 (0.07)	0.25	-0.53	0.33	0.09
$\rho(x_{ht+2}, x_{mt})$	-0.18 (0.09)	0.04	0.45	-0.09	0.37
$\rho(x_{ht-2}, y_t)$	0.66 (0.09)	0.47	0.03	0.45	0.19
$\rho(x_{ht}, y_t)$	0.62 (0.09)	0.87	0.28	0.90	0.82
$\rho(x_{ht+2}, y_t)$	0.07 (0.12)	0.12	0.61	0.03	0.32
$\rho(x_{mt-2}, y_t)$	0.29 (0.08)	0.30	0.44	0.26	0.48
$\rho(x_{mt}, y_t)$	0.76 (0.04)	0.70	0.66	0.71	0.82
$\rho(x_{mt+2}, y_t)$	0.72 (0.07)	0.69	-0.05	0.87	0.29
$\sigma_{x_h}/\sigma_{x_m}$	1.30 (0.12)	1.28	0.62	1.61	0.62
		Panel C: Test of Overidentifying Restrictions			
J		27.8	426	5.51	128
[p-value]		[0.13]	[0]	[0.63]	[0.0007]

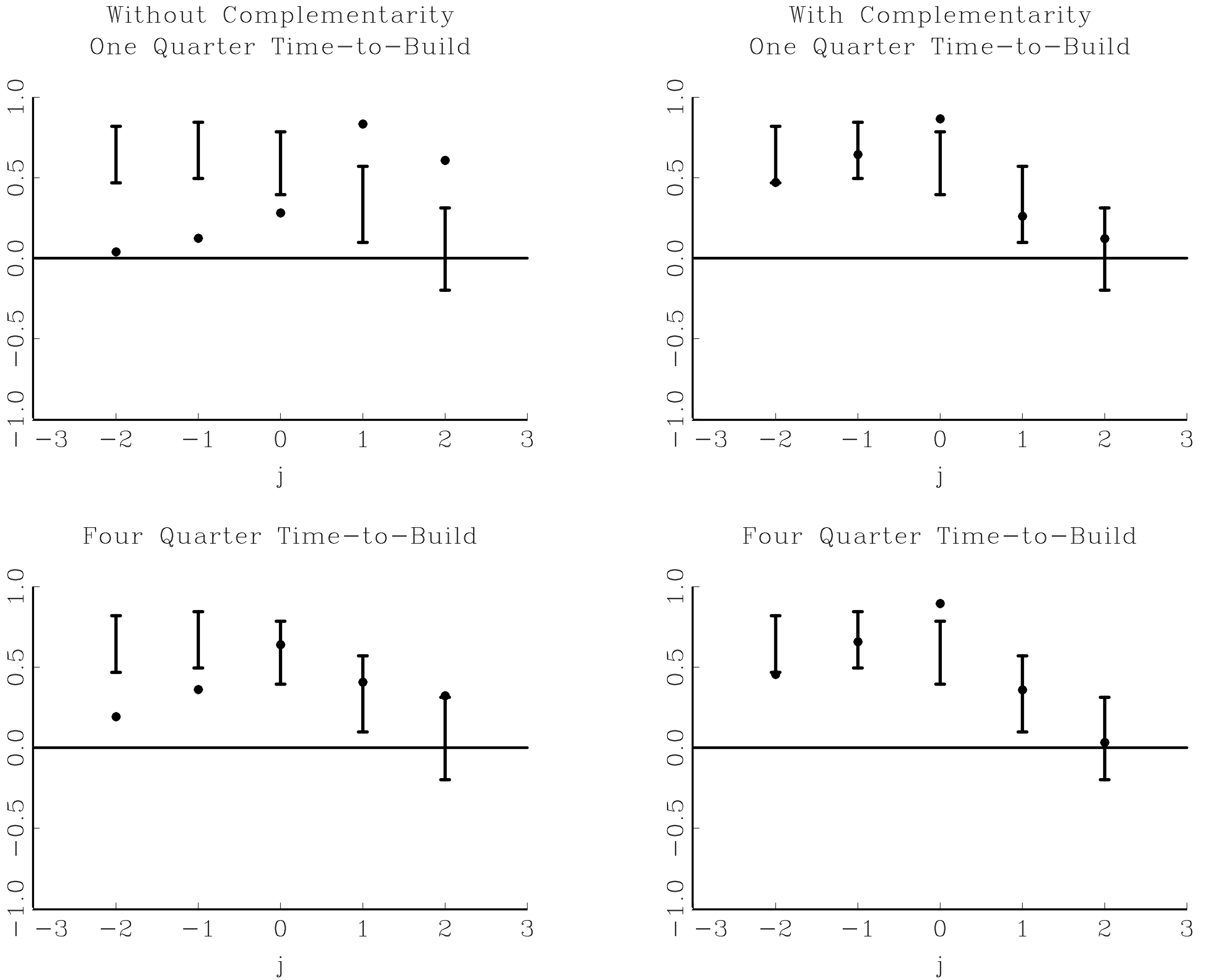
Notes: a – σ_l denotes standard deviation of variable l, $\rho(l_t, q_s)$ denotes cross-correlation between variable l_t and variable q_s, and $x = p_m x_m + p_h x_h$; b – Point estimate with standard error in parenthesis based on U.S. data over the sample period 1948:I-2004:IV. Standard errors estimated by GMM. For estimation of the relevant zero-frequency spectral density, a Bartlett window truncated at lag five was used. For data sources, see the appendix; c – Parameter values corresponding to the different specifications are described in the text.

Figure 1. Correlations of Household Investment at t+j with Business Investment at t



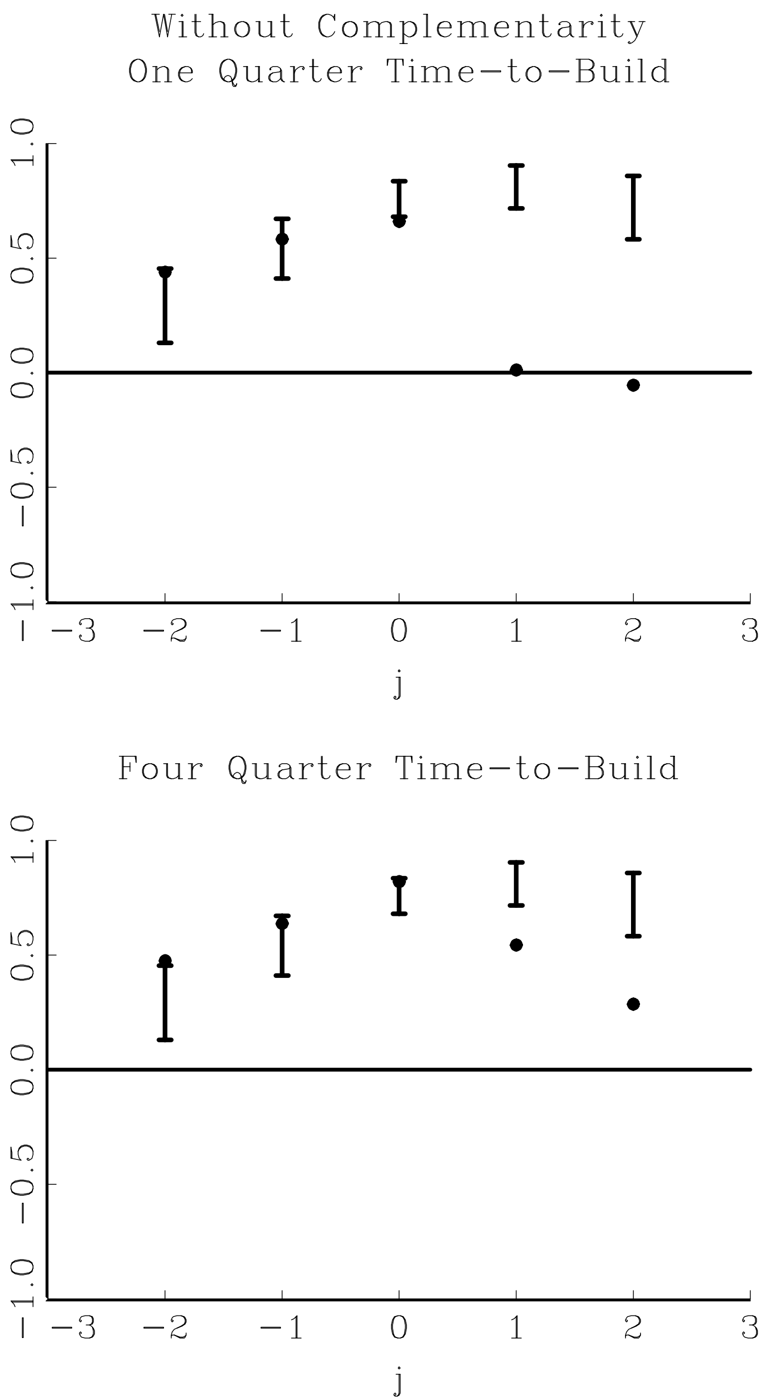
Notes: Black dots are model predictions. Lines with hash marks indicate plus and minus two standard deviation confindence intervals for the indicated empirical correlation.

Figure 2. Correlations of Household Investment at t+j with Output at t



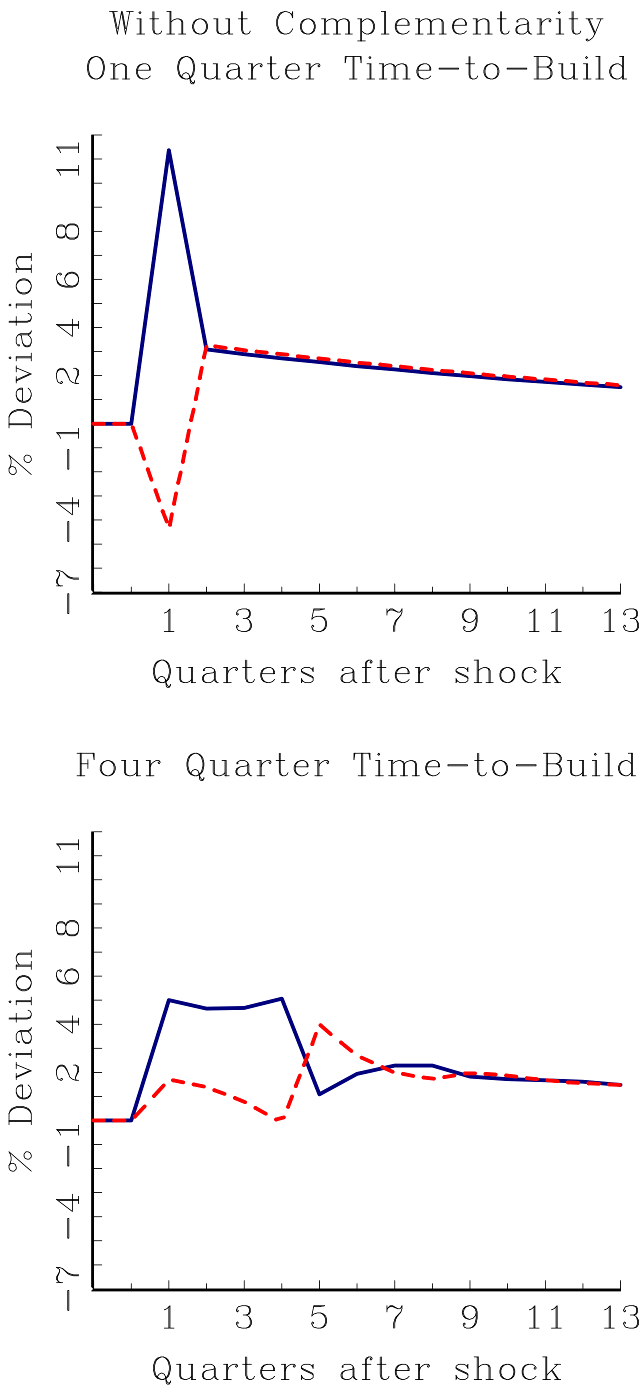
Note: See notes to figure 2.

Figure 3. Correlations of Business Investment at t+j with Output at t



Note: See notes to figure 2.

Figure 4. Responses of Household and Business Investment to a Technology Shock



Notes: Solid lines -- business investment, dashed lines -- household investment. The shock occurs in period 1.

Figure 5. Impact of Household Capital Complementarity on Investment Dynamics