

# The Return to Capital and the Business Cycle\*

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# 1 Introduction

There has been considerable progress in accounting for business cycle fluctuations in aggregate quantities. Using the real business cycle (RBC) framework developed by [Kydland and Prescott \(1982\)](#), many studies have replicated the observed comovements and volatilities of aggregate variables such as output, consumption, investment and hours. Despite the successes achieved in accounting for the aggregate quantities, business cycle models have been unable to replicate features of relative prices. In the basic real business cycle model, it is optimal to smooth consumption in response to fluctuations in total factor productivity. In such a model, [Rouwenhorst \(1995\)](#) has shown that the intertemporal marginal rate of substitution (IMRS) or the stochastic discount factor is not volatile enough to account for the time series properties of S&P 500 returns.<sup>1</sup>

In RBC theory, the key intertemporal relative price is the real rate of return on a representative unit of capital. As noted by [Mulligan \(2002\)](#) in the context of intertemporal substitution in consumption, in aggregate models this relative price is *not* the rate of return on S&P 500 assets. Since tangible assets of S&P 500 firms are a fraction of the aggregate capital, the link between theory and measurement is, at best, weak. (Tangible assets of the corporate sector roughly 40% of the total capital stock, so the S&P 500 firms constitute less than 40% of the total.) This weak link between theory and measurement would not be problematic for quantitative exercises if the empirical properties of the return to capital were the same as those of the S&P 500 returns. We construct a time series for the return to capital and show that its time series properties differ significantly from those of the S&P 500 returns. We compute the real after-tax rate of return on a representative unit of capital by summing all of the income generated by market capital, subtracting the relevant taxes and dividing by the stock of market capital that generated the income.<sup>2</sup> S&P 500

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<sup>1</sup>[Jermann \(1998\)](#) examines an RBC model with habit persistence and adjustment costs to capital while [Boldrin, Christiano and Fisher \(2001\)](#) examine a two-sector growth model with habit persistence and restrictions on factor mobility across sectors. Both papers account for almost the entire observed volatility in S&P 500 returns.

<sup>2</sup>The stock of market capital refers to the sum of: private nonresidential structures, private nonresidential

return, on the other hand, is measured as  $\frac{p_{t+1}+d_{t+1}}{p_t} - 1$  where  $p_s$  denotes the price and  $d_s$  denotes the dividend in period  $s$ . It is well known that the volatility in the S&P 500 return is largely due to the volatility in prices. In the typical one-sector RBC model, the price of capital in terms of output is fixed, so the fluctuations in the return to capital are not due to price variations. Our calculation of the return to capital is consistent with the RBC theory. Using our measurement, we reexamine the return implications of the standard RBC model.

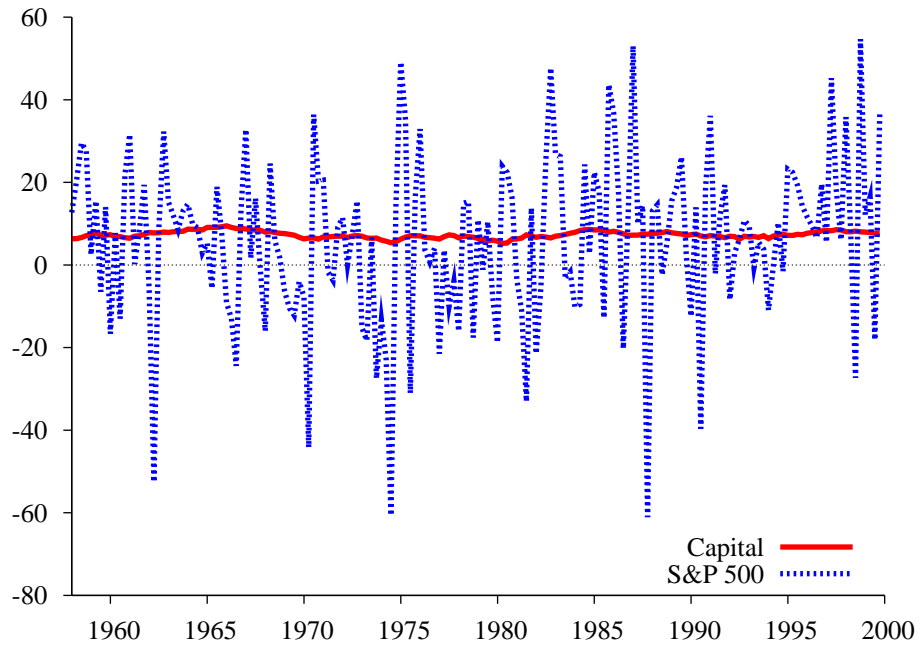
There are several findings of note. First, the average annual after-tax rate of return to capital is 7.33%, while the mean after-tax rate of return on the S&P 500 is 6.04%, over the period 1958:Q1-1999:Q4. Our calculations, described in [section 3](#), take into account all taxes paid by the owners of all market capital. In contrast, [McGrattan and Prescott \(2003\)](#) find a mean after-tax return of 5.4% for the *noncorporate* sector during 1880-2002. [Poterba \(1998\)](#), using data from 1959-96 for the *nonfinancial corporate* sector, finds a mean return of 3.9%. [Mulligan \(2002\)](#) calculates the mean return on capital excluding inventories, equipment and software to be around 6% between the late 1930s and 2000.

The second notable finding is that the return to capital is very smooth relative to the S&P 500 returns; see [Figure 1](#). The percent standard deviation of the S&P 500 quarterly returns over the 1958:1-1999:4 sample period is 327% while the volatility of our constructed return to capital is only about 11.5%.

By way of contrast, [Poterba \(1998\)](#) finds more variability in the after-tax rate of return to nonfinancial corporate capital. For example, he finds that the average return over the 1990-96 subperiod is 5.0%, while over the period 1970-79 the average rate of return is 2.9%. When our data is broken down by subperiod, there is much less variation: the average rate of return is 7.47% in the 1990-96 subperiod and 7.45% in the 1970-79 subperiod.

The third finding is that the basic RBC model generates an average after-tax rate of return to capital that is close to that seen in the data, even though the model is not calibrated to equipment and software, and private inventories.

Figure 1: After-tax return to the S&P 500 and Capital



brated to match this return. It also accounts for almost 30% of the volatility in the return to capital. [Rouwenhorst \(1995\)](#) finds that the basic RBC model captures about 4% of the volatility in S&P 500 returns.

The rest of the paper is organized as follows. In the next section we set up the economic environment and describe the equilibrium. Our model is essentially the same as the basic RBC model in [Prescott \(1986\)](#). In [section 3](#), we describe our measurement of tax rates and return to capital. In [section 4](#), we study the quantitative implications of the model.

## 2 Economic Environment

Since the economic environment should be easily recognizable to those familiar with the macroeconomics literature of the past two decades, the model's description is fairly brief. The competitive equilibrium for this model is standard.

## 2.1 Firms

Taking as given the real wage rate,  $w_t$  and the rental rate for capital,  $r_t$ , the typical firm rents capital,  $k_t$ , and hires labor,  $h_t$ , to maximize profits,

$$y_t - w_t h_t - r_t k_t.$$

Output is produced according to a constant-returns-to-scale, Cobb-Douglas production function,

$$y_t = z_t k_t^\alpha (g^t h_t)^{1-\alpha}$$

where  $g$  is the growth rate of labor-augmenting technological change, and  $z_t$  is a random shock to production.  $z_t$  follows the stochastic process,

$$\ln z_t = \rho \ln z_{t-1} + \epsilon_t$$

where  $\epsilon_t \sim N(0, \sigma_\epsilon^2)$ .

The firm's output can be converted into either consumption,  $c_t$ , or investment goods,  $i_t$ :

$$c_t + i_t = y_t.$$

## 2.2 Households

The representative household has preferences over streams of consumption,  $c_t$ , and leisure,  $\ell_t$ , summarized by

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, \ell_t). \quad (1)$$

The period utility function has the functional form,

$$U(c, \ell) = \begin{cases} \frac{[c\ell^\omega]^{1-\gamma}}{1-\gamma} & \text{if } 0 < \gamma < 1 \text{ or } \gamma > 1, \\ \ln c + \omega \ln \ell & \text{if } \gamma = 1. \end{cases}$$

The household allocates its one unit of time endowment between leisure,  $\ell_t$ , and work,

$h_t$ :

$$\ell_t + h_t = 1. \quad (2)$$

The household faces a budget constraint,

$$c_t + i_t = (1 - \tau_\ell)w_t h_t + (1 - \tau_k)r_t k_t + T_t, \quad (3)$$

where  $\tau_\ell$  is the tax rate on labor income,  $\tau_k$  is the tax rate on gross capital income, and  $T_t$  is a lump-sum transfer received from the government. The household's capital stock evolves according to

$$k_{t+1} = (1 - \delta)k_t + i_t \quad (4)$$

where  $\delta$  is the depreciation rate of capital.

The household's problem is to choose contingent sequences for consumption,  $c_t$ , leisure,  $\ell_t$ , work,  $h_t$ , investment,  $i_t$ , and capital,  $k_{t+1}$ , so as to maximize lifetime utility, (1), subject to the constraints, (2)–(4), taking as given the wage rate,  $w_t$ , rental rate,  $r_t$ , taxes,  $\tau_\ell$  and  $\tau_k$  and transfers,  $T_t$ .

## 2.3 Government

The government levies time-invariant taxes on capital income,  $\tau_k$ , and on labor income,  $\tau_\ell$ . It also makes a lump-sum rebate to households,  $T_t$ . Government does not directly consume resources; the government sector is included because capital income taxes distort the return to capital, and the focus of this paper is on the after-tax return on capital. The government's budget constraint, then, is

$$T_t = \tau_k r_t k_t + \tau_\ell w_t h_t.$$

## 3 Measurement

In this section we describe the empirical counterparts to our theory in the previous section. As part of this description, we construct a time series for the rate of return to capital.

Construction of the empirical counterparts to the model's variables follows standard procedures in the literature such as those in [Cooley and Prescott \(1995\)](#) and [Gomme and Rupert \(forthcoming\)](#). The National Income and Product Accounts (NIPA) are the source for much of the derivations. [Table 1](#) provides the relevant details. Variables are converted to per capita values using the civilian noninstitutionalized population aged 16 and over. Nominal variables are converted to real ones using a deflator for consumption (nondurables and services), which was constructed from nominal and real consumption so as to conform to our measure of market consumption; on this point, see [Greenwood, Hercowitz and Krusell \(1997\)](#).

Table 1: Data Description

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$Y$	Nominal market output: GROSS DOMESTIC PRODUCT less GROSS HOUSING PRODUCT
$Y^P$	Nominal private market output: GROSS DOMESTIC PRODUCT less GROSS HOUSING PRODUCT less GOVERNMENT COMPENSATION OF EMPLOYEES
$C_m$	Nominal market consumption: PERSONAL CONSUMPTION EXPENDITURES ON NONDURABLES and SERVICES less Gross HOUSING PRODUCT
$X_m$	Nominal market investment: NONRESIDENTIAL FIXED INVESTMENT plus CHANGE IN PRIVATE INVENTORIES
$X_h$	Nominal home investment: RESIDENTIAL FIXED INVESTMENT plus PERSONAL CONSUMPTION EXPENDITURES ON DURABLES
$Y^{LP}$	Nominal private unambiguous labor income: COMPENSATION OF EMPLOYEES less HOUSING COMPENSATION OF EMPLOYEES less GOVERNMENT COMPENSATION OF EMPLOYEES
$Y^{KP}$	Nominal private unambiguous capital income: RENTAL INCOME plus NET INTEREST INCOME plus CORPORATE PROFITS less HOUSING RENTAL INCOME less HOUSING NET INTEREST INCOME less HOUSING CORPORATE PROFITS
$Y^{AP}$	Nominal private ambiguous income: PROPRIETORS' INCOME less HOUSING PROPRIETORS' INCOME plus (NET NATIONAL PRODUCT less NET HOUSING PRODUCT) less (NATIONAL INCOME less HOUSING NATIONAL INCOME)
$Y^{LG}$	Nominal government labor income: GOVERNMENT COMPENSATION OF EMPLOYEES
$POP$	Population: Civilian noninstitutionalized population aged 16 and over

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In the U.S. economy, the real after-tax rate of return on a representative unit of market capital can be calculated by summing all of the income generated by market capital, subtracting the relevant taxes, and dividing by the stock of capital that generated the income. The income and tax data are found in the NIPA, while the capital stock data is obtained from the Bureau of Economic Analysis (BEA).

There are several issues complicating such a calculation, however. We are interested in obtaining mean rates of return as well as cyclical properties of the return at a quarterly frequency. Unfortunately not all of the necessary data are available quarterly. After presenting the calculations, we will describe the data that is not available at a quarterly frequency, then explain our imputation procedure to construct a quarterly series.

Since we are interested in the return generated from aggregate capital, we must include the income earned from both the corporate and noncorporate sectors. One concern is the income accruing to proprietors. Evidently, this income is partly generated from capital and partly from labor. The generally accepted practice is to allocate proprietors' income to capital and labor in the same proportion as calculated for the economy as a whole; see, for example, [Cooley and Prescott \(1995\)](#) and [Gomme and Rupert \(forthcoming\)](#). That is, if labor's share of national income is  $1 - \alpha$  and capital's share is  $\alpha$ , we attribute the fraction  $1 - \alpha$  of proprietor's income to labor and the fraction  $\alpha$  to capital.

We remove income associated with the housing sector because we are interested in the return to market capital. Our measure of the capital stock will, then, include only those parts that are used in producing market output, and so will exclude residential structures and consumer durables.

While most of the taxes levied against capital income can be obtained fairly directly from the data, those paid by households must be imputed. To obtain the tax rate on general *household income*, we follow the basic methodology of [Mendoza, Razin and Tesar \(1994\)](#) and [Carey and Tchilinguirian \(2000\)](#). This tax rate,  $\tau_h$ , is computed as:

$$\tau_h = \frac{\text{PERSONAL CURRENT TAXES}}{\text{NET INTEREST} + \text{PROPRIETORS' INCOME} + \text{RENTAL INCOME} + \text{WAGES AND SALARIES}}.$$

The tax rate  $\tau_h$  – distinct from  $\tau_\ell$  and  $\tau_k$  – is an intermediate input into subsequent calculations of the rate of return to capital.

After-tax capital income can be written as:

$$\begin{aligned} Y_{AT} = & \text{NET OPERATING SURPLUS} \\ & - \text{HOUSING NET OPERATING SURPLUS} \\ & - (1 - \alpha)(\text{PROPRIETOR'S INCOME} - \text{HOUSING PROPRIETOR'S INCOME}) \\ & - \tau_h(\text{NET INTEREST} - \text{HOUSING NET INTEREST}) \\ & - \alpha\tau_h(\text{PROPRIETOR'S INCOME} - \text{HOUSING PROPRIETOR'S INCOME}) \\ & - \tau_h(\text{RENTAL INCOME} - \text{HOUSING RENTAL INCOME}) \\ & - \text{TAXES ON CORPORATE INCOME} \\ & - \text{STATE AND LOCAL OTHER TAXES.} \end{aligned}$$

Net operating surplus is defined as value added minus depreciation and payments to labor. As discussed above, the income flows and tax rates have been modified to subtract out the income generated from the housing sector.

Dividing after-tax capital income,  $Y_{AT}$ , by the stock of market capital (inventories, market structures and equipment & software) gives the return to capital. After-tax capital income and the stock of inventories are converted to real by dividing by the price deflator for personal consumption expenditures while market structures and equipment & software are reported by the BEA in real terms. Thus, the real return can be determined by

$$R_{AT} = \frac{Y_{AT}}{\text{INVENTORIES} + \text{STRUCTURES} + \text{EQUIPMENT AND SOFTWARE}}.$$

### 3.1 Annual to Quarterly Conversions

Several series are not available quarterly. Different methods are used to convert the annual series to quarterly. To start, the series LOCAL OTHER TAXES covers such things as

licensing fees. It seems reasonable, then, to divide this figure equally across the four quarters.

A quarterly series for INVENTORIES is constructed as follows. NIPA reports inventories as of the beginning of the year, so the annual inventory observation corresponds to the first quarter, Q1, of the relevant year. For Q2, take the Q1 observation and add  $\frac{1}{4}$  of the annual NEUTRAL HOLDING GAINS OR LOSSES, and  $\frac{1}{4}$  of the annual REAL HOLDING GAINS OR LOSSES. Finally, add  $\frac{1}{4}$  of the CHANGE IN INVENTORIES. This procedure is then repeated for the other quarters, with the obvious modifications. Holding gains/losses are reported up to 1999:Q4, a fact that limits our ability to provide more up-to-date measures of the capital stock, and the return to capital.

Quarterly values for all of the housing flows are imputed with the exception of GROSS HOUSING VALUE ADDED (GHVA), which is available quarterly. To understand the approach taken here, we will explain the calculation for NET OPERATING SURPLUS as an example. Take the observation for GHVA (quarterly), multiply by NET OPERATING SURPLUS (annual) divided by GHVA (annual), for the relevant year. That is, apportion the quarterly GHVA to its constituent components using the annual ratios for the appropriate year. This strategy is also used to impute NET INTEREST, PROPRIETORS' INCOME and RENTAL INCOME for the housing sector.

Quarterly capital stocks are constructed from annual capital stocks and quarterly investment flows. This procedure requires solving for the depreciation rate that makes the annual capital stocks line up with Q4 of our quarterly capital stock, and be consistent

with the quarterly investment flows. For example:

$$K_{1949Q4} = K_{1949} \text{ (the annual observation)}$$

$$K_{1950Q1} = (1 - \delta_{1950})K_{1949Q4} + I_{1950Q1}$$

$$K_{1950Q2} = (1 - \delta_{1950})K_{1950Q1} + I_{1950Q2}$$

$$K_{1950Q3} = (1 - \delta_{1950})K_{1950Q2} + I_{1950Q3}$$

$$K_{1950Q4} = (1 - \delta_{1950})K_{1950Q3} + I_{1950Q4}$$

$$K_{1950Q4} = K_{1950} \text{ (the annual observation)}$$

In effect, there are 4 equations (the middle 4) in 4 unknowns:  $K_{1950Q1}$ ,  $K_{1950Q2}$ ,  $K_{1950Q3}$  and  $\delta_{1950}$ .

### 3.2 The Real Return to Capital

The results for the tax rate on household income,  $\tau_h$  and the real return to capital are shown in [Table 2](#). The rate of return to capital averaged 7.33% over the period 1958:Q1-1999:Q4 (see [Table 3](#)). This value is somewhat higher than the mean return reported by others. For example, [Poterba \(1998\)](#) used data from 1959 to 1996 for the nonfinancial corporate sector, and found a mean after-tax return of 3.9%. There are two reasons for the large difference between our return and [Poterba's](#). First, we include both the financial corporate sector as well as the entire noncorporate sector. While the financial corporate sector is relatively small, capital's share of income from that sector is considerably larger than that observed in the nonfinancial sector. This contributes to a high measured return to capital for the financial sector. Second, [Poterba](#) computes marginal tax rates which he then applies to the rates of return. These marginal tax calculations are difficult to replicate, and we take the more straightforward approach of computing average after-tax returns. [Poterba's](#) average marginal tax rate is roughly 55% whereas our average tax rate is around 28%. Pre-tax, [Poterba](#) computes an average return of 8.5% compared with our figure of 10.7%.

Table 2: U.S. Return to Capital and Tax Rate on Household Income

Year	Return to Capital				Tax Rate, $\tau_h$			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1958	6.34	6.38	6.65	7.09	12.26	12.09	12.24	12.17
1959	7.23	7.76	7.18	7.23	12.42	12.47	12.65	12.80
1960	7.31	6.91	6.87	6.60	13.01	13.09	13.19	13.15
1961	6.48	6.95	7.07	7.38	13.09	13.04	12.95	12.85
1962	7.87	7.77	7.80	7.95	13.00	13.18	13.43	13.62
1963	7.88	8.06	8.08	8.15	13.61	13.50	13.40	13.31
1964	8.67	8.63	8.66	8.48	12.75	11.56	11.78	11.96
1965	9.10	9.10	9.12	9.25	12.57	12.66	12.13	12.07
1966	9.49	9.10	8.84	8.86	12.39	12.98	13.14	13.42
1967	8.70	8.53	8.45	8.39	13.35	13.16	13.43	13.59
1968	7.95	8.08	7.87	7.69	13.71	13.92	15.28	15.63
1969	7.62	7.40	7.23	6.72	16.37	16.46	15.77	15.74
1970	6.32	6.51	6.54	6.25	15.36	15.38	14.44	14.50
1971	6.81	6.80	6.91	6.96	13.71	13.79	13.80	13.97
1972	6.95	6.67	7.01	7.14	15.44	15.61	15.28	14.99
1973	6.98	6.56	6.45	6.52	14.58	14.50	14.68	14.82
1974	6.02	5.72	5.38	5.64	14.95	15.37	15.58	15.59
1975	6.26	6.74	7.10	7.07	15.61	11.85	14.54	14.68
1976	7.05	6.72	6.62	6.47	14.68	15.00	15.29	15.50
1977	6.30	6.88	7.30	7.11	15.68	15.75	15.55	15.70
1978	6.57	6.99	6.85	6.73	15.62	15.81	16.30	16.55
1979	6.42	6.15	5.88	6.00	16.43	16.65	16.98	17.04
1980	5.77	5.23	5.31	6.27	16.54	16.96	17.12	17.10
1981	6.28	6.52	7.29	6.94	17.38	17.66	17.77	17.37
1982	6.70	6.90	6.78	6.55	17.21	17.34	16.76	16.93
1983	6.95	7.12	7.39	7.69	16.45	16.60	15.59	15.52
1984	7.88	8.32	8.53	8.60	15.26	15.16	15.30	15.50
1985	8.49	8.50	8.29	7.97	16.57	14.74	15.85	15.79
1986	8.17	7.88	7.53	7.17	15.43	15.37	15.52	15.91
1987	7.21	7.21	7.46	7.46	15.43	17.26	16.17	16.32
1988	7.69	7.68	7.83	8.11	15.86	15.44	15.39	15.42
1989	7.80	7.65	7.50	7.13	16.06	16.35	16.37	16.40
1990	7.36	7.49	7.02	6.82	16.13	16.20	16.17	16.17
1991	7.12	6.98	6.86	6.61	15.70	15.74	15.74	15.85
1992	6.96	6.87	6.22	6.96	15.30	15.56	15.71	16.06
1993	6.75	6.89	6.66	7.10	15.44	15.89	16.19	16.40
1994	6.39	7.00	7.24	7.40	16.14	16.44	16.18	16.16
1995	7.17	7.15	7.41	7.32	16.35	16.73	16.67	16.82
1996	7.68	7.86	7.93	8.26	17.30	17.72	17.55	17.68
1997	8.30	8.29	8.56	8.49	18.08	18.17	18.35	18.49
1998	8.07	8.03	8.19	8.04	18.51	18.63	18.63	18.75
1999	7.95	7.84	7.69	7.76	18.64	18.76	18.93	19.06

Table 3: Returns Data: Selected Moments

	Mean	% Standard Deviation
<i>After-tax</i>		
Market capital	7.33	11.49
All capital	4.94	10.14
S&P 500	6.04	326.66
<i>Pre-tax</i>		
Market capital	10.66	11.25
All capital	6.74	9.08
S&P 500	9.17	341.17

Mulligan (2002) finds the mean after-tax rate of return on capital to be roughly 6%. Conceptually, his measurement of the return to capital is fairly close to ours. Relative to our measure of capital, Mulligan excludes inventories and equipment & software but includes residential structures. Since the stock of residential structures is far larger than the stocks of inventories and equipment & software, it is not surprising that Mulligan's estimate of the return to capital is smaller than ours. If we include the stock of residential structures in our measure of capital, we obtain an average after-tax return to capital of approximately 5%.

McGrattan and Prescott (2003) found a mean after-tax return of 5.4% for the noncorporate sector. Their justification for focusing on the noncorporate sector is that intangible assets are concentrated in the corporate sector, and that investment in intangible assets is omitted from NIPA. To compute the return to tangible assets, McGrattan and Prescott therefore focus their measurement on the noncorporate sector. They also adjust their returns for diversification costs and taxes.

As documented in Table 3 (and visually in Figure 1) the rate of return to capital is very smooth relative to the S&P 500 return—the latter nearly 30 times as volatile. Even when our data is broken down by subperiod, there is much less variation: the mean rate of return is 7.47% in the 1990-96 subperiod and 7.45% in the 1970-79 subperiod. However, Poterba (1998) finds substantial differences in the mean rate of return for the nonfinancial

corporate sector when compared across decades. For example, the average return over the 1990-96 subperiod is 5.0%, while over the period 1970-79 he calculates the average rate of return as 2.9%. So it appears that the return to capital does not show as much variation as that of the smaller nonfinancial corporate sector.

## 4 Quantitative Implications

### 4.1 Parameters

The calibration procedure involves choosing functional forms for the utility and production functions, and assigning values to the parameters of the model based on either micro-evidence or long run growth facts. [Cooley and Prescott \(1995\)](#) provide an overview of the general strategy. A more detailed description of the calibration procedure can be found in [Gomme and Rupert \(forthcoming\)](#).

In particular,  $\alpha$  is set to match NIPA data. The parameters  $\rho$  and  $\sigma_\epsilon$  are estimated from regressions using U.S. Solow residuals. The coefficient of relative risk aversion,  $\gamma$ , is set to 1. The growth rate,  $g$ , is chosen so that the average growth rate of real per capita output matches that in the U.S. data. The depreciation rate,  $\delta$ , is set to match BEA data on depreciation and capital stocks. The remaining parameters,  $\omega$  and  $\beta$ , are chosen so that in steady state,  $h$  and  $i/y$  are equal to what is observed in the data. The benchmark parameter values of our model are in [Table 4](#). The tax rates on capital income,  $\tau_k$ , and on labor income,  $\tau_\ell$ , are averages over the years 1958:1-1999:4 taken from [Gomme and Rupert \(forthcoming\)](#). For completeness, data on  $\tau_\ell$  and  $\tau_k$  are reported in [Table 5](#).

The steady state of the model for the benchmark parameters are summarized in [Table 6](#). The model is solved by applying a generalized Schur technique to a first-order log approximation of the decision rules around steady state; see [Klein \(2000\)](#).

Table 4: Parameter Values

$\beta$	0.9881
$\gamma$	1.0000
$\omega$	1.2865
$\alpha$	0.2830
$\delta$	0.0181
$\tau_k$	0.2868
$\tau_\ell$	0.2200
$\rho$	0.96405
$\sigma_\epsilon$	0.00818

## 4.2 Findings

The business cycle moments for the United States covering the period 1958:1-1999:4 are presented in [Table 7](#). With the exception of the returns data, the underlying data has been detrended by taking the logarithm and applying the Hodrick-Prescott filter with a smoothing parameter of 1600. As shown in [Figure 1](#), the returns to the S&P 500 are occasionally negative and so the usual business cycle detrending procedure cannot be applied. Instead, returns are expressed as a percentage deviation from their sample averages, a procedure that is in the same spirit as the Hodrick-Prescott filter.

On the real side, the benchmark economy shares many of the successes (and failures) of other RBC models. Models calibrated to the observed Solow residual process typically underpredict the volatility of output; so does our model. In the data, consumption varies less than output while investment varies more; our model delivers this ranking, but underpredicts the volatility of consumption while exaggerating that of investment.

Next, consider the returns data. The model does quite well in terms of the average return to capital, predicting a value of 6.6% compared to 7.3% in the data. Keep in mind that the model is not calibrated to the average rate of return. In the U.S. economy, the return to capital is roughly 6.7 times more volatile than output, is procyclical, and slightly leads the cycle. A similar story can be told for the return to all capital (that is, including the residential structures and consumer durables). S&P 500 returns are far more volatile – roughly 191 times that of output. These returns are also countercyclical. To the extent

Table 5: U.S. Tax Rates on Labor and Capital Income

Year	Tax Rate, $\tau_\ell$				Tax Rate, $\tau_k$			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
1958	15.39	15.24	15.33	15.21	31.64	31.57	32.44	33.36
1959	16.01	16.02	16.17	16.26	33.70	33.83	33.51	33.34
1960	17.07	17.12	17.19	17.13	34.37	34.07	33.73	33.67
1961	17.13	17.07	16.97	16.84	33.78	33.71	34.03	34.38
1962	17.28	17.41	17.63	17.77	33.04	33.15	33.56	33.37
1963	18.19	18.07	17.97	17.83	33.45	33.68	33.85	33.80
1964	17.23	16.09	16.24	16.36	33.06	32.76	32.92	32.93
1965	16.88	16.94	16.42	16.31	32.58	32.62	32.31	32.52
1966	17.72	18.21	18.43	18.64	32.46	32.82	32.85	32.41
1967	18.76	18.70	18.91	19.05	32.45	32.49	32.60	33.18
1968	19.24	19.40	20.59	20.85	35.14	34.93	35.39	35.63
1969	21.88	21.92	21.24	21.19	35.96	35.81	35.36	36.03
1970	20.83	20.81	19.92	19.90	35.55	35.21	35.20	35.27
1971	19.54	19.52	19.45	19.54	34.93	34.96	34.36	34.11
1972	21.37	21.44	21.07	20.66	34.67	33.99	34.02	34.14
1973	21.50	21.34	21.45	21.47	34.39	34.43	34.09	33.96
1974	21.99	22.35	22.47	22.36	34.05	34.46	35.61	33.50
1975	22.38	19.00	21.24	21.27	31.06	29.40	31.13	31.13
1976	21.58	21.77	21.93	22.01	32.02	32.22	32.16	31.95
1977	22.33	22.33	22.09	22.10	32.41	31.85	31.11	31.06
1978	22.44	22.54	22.90	23.05	30.52	30.95	29.89	30.07
1979	23.45	23.56	23.79	23.76	29.71	29.61	29.49	28.82
1980	23.46	23.71	23.82	23.74	29.48	27.80	28.15	27.67
1981	24.69	24.90	24.97	24.60	27.24	26.12	25.62	24.99
1982	24.71	24.75	24.22	24.28	24.30	24.22	24.03	23.71
1983	24.17	24.26	23.39	23.30	23.44	24.41	24.42	24.38
1984	23.41	23.28	23.36	23.50	24.87	24.35	23.41	23.37
1985	24.64	23.09	24.02	23.98	24.42	23.49	24.09	24.23
1986	23.87	23.81	23.92	24.23	24.60	24.85	25.24	26.31
1987	23.88	25.37	24.43	24.54	25.72	27.08	26.85	26.88
1988	24.60	24.24	24.17	24.21	25.78	25.99	26.05	26.04
1989	24.81	25.05	25.04	25.05	27.03	26.76	25.98	26.44
1990	24.93	24.92	24.92	24.86	26.10	26.23	26.98	26.76
1991	24.70	24.69	24.69	24.71	25.81	26.10	26.42	26.61
1992	24.32	24.48	24.55	24.77	26.64	27.05	25.64	26.78
1993	24.33	24.73	24.97	25.15	26.62	27.06	26.96	27.35
1994	25.04	25.32	25.11	25.11	26.35	27.47	27.38	27.31
1995	25.32	25.65	25.61	25.74	27.18	27.20	26.95	26.64
1996	26.13	26.47	26.35	26.46	26.78	26.92	26.67	26.38
1997	26.85	26.93	27.06	27.17	26.52	26.53	26.52	26.47
1998	27.14	27.21	27.17	27.23	26.89	26.81	26.64	26.39
1999	27.21	27.26	27.34	27.40	26.39	26.54	26.53	26.68

Table 6: Steady State Values

Hours	0.255
Consumption	0.58
Output	0.67
Capital-output ratio	5.87
Investment-output ratio	0.13
Growth rate of output	0.42%

that stock market returns reflect the marginal product of capital, it is odd that its return is countercyclical, albeit weakly. These business cycle facts are not very sensitive to whether the returns are measured after-tax or pre-tax.

The model’s prediction for the return to capital – the after-tax marginal product of capital less depreciation – is also summarized in [Table 7](#). The model predicts that this return is 3.2 times more volatile than output and is strongly procyclical. In the data, the return to capital is 6.7 times as volatile as output, so the model captures approximately half of the relative volatility in the return to capital. If the target was to match the volatility of S&P 500 returns, the model captures less than 2% of this relative variability. Our point is that a standard RBC model captures a sizeable fraction of the volatility in the return to capital when this return is appropriately measured – that is, when the return to capital is measured in the data in a manner consistent with how this object is constructed in the model.

### 4.3 Alternative Models and Parameterizations

Here, we consider three variants on the benchmark model. The common theme is to explore the model’s implications for the volatility of the return to capital. Consider the intertemporal equation governing the accumulation of capital,

$$1 = E_t \left\{ \left( \beta \frac{U_{c,t+1}}{U_{c,t}} \right) \left[ (1 - \tau_k) \alpha \left( \frac{y_{t+1}}{k_{t+1}} \right) + 1 - \delta \right] \right\}. \quad (5)$$

The first term on the right-hand side is often referred to as the stochastic discount factor or the intertemporal marginal rate of substitution for consumption. The second term is the

Table 7: Selected Business Cycle Moments

	Standard Deviation	Cross Correlation of Real Output With								
		$x_{t-4}$	$x_{t-3}$	$x_{t-2}$	$x_{t-1}$	$x_t$	$x_{t+1}$	$x_{t+2}$	$x_{t+3}$	$x_{t+4}$
<b>U.S. Data</b>										
Output	1.71	0.16	0.40	0.64	0.85	1.00	0.85	0.64	0.40	0.16
Consumption	0.86	0.25	0.45	0.63	0.76	0.79	0.70	0.56	0.39	0.19
Investment	4.17	-0.18	-0.01	0.23	0.46	0.69	0.80	0.78	0.69	0.51
Hours	1.70	-0.13	0.08	0.33	0.59	0.81	0.88	0.83	0.70	0.52
Productivity	1.05	0.47	0.52	0.51	0.43	0.31	-0.05	-0.31	-0.49	-0.58
Capital	1.00	0.12	0.07	0.01	-0.08	-0.18	-0.28	-0.36	-0.41	-0.41
<i>After-tax returns</i>										
Market capital	11.49	0.27	0.30	0.30	0.30	0.27	0.14	0.01	-0.11	-0.23
All capital	10.14	0.22	0.23	0.22	0.22	0.19	0.08	-0.03	-0.13	-0.23
S&P 500	326.66	0.17	0.13	0.06	-0.11	-0.21	-0.22	-0.18	-0.12	-0.04
<i>Pre-tax returns</i>										
Market capital	11.25	0.25	0.30	0.33	0.35	0.34	0.21	0.09	-0.03	-0.14
All capital	9.08	0.23	0.27	0.29	0.31	0.30	0.17	0.06	-0.06	-0.16
S&P 500	341.17	0.17	0.14	0.07	-0.10	-0.21	-0.22	-0.18	-0.13	-0.05
<b>Benchmark Model</b>										
Output	1.49	0.09	0.25	0.45	0.70	1.00	0.70	0.45	0.25	0.09
Consumption	0.70	-0.04	0.12	0.34	0.62	0.96	0.76	0.58	0.42	0.28
Investment	7.24	0.17	0.32	0.50	0.72	0.98	0.62	0.34	0.12	-0.04
Hours	0.63	0.19	0.33	0.51	0.72	0.97	0.60	0.31	0.09	-0.08
Productivity	0.89	0.01	0.18	0.39	0.66	0.99	0.74	0.53	0.35	0.20
Capital	0.54	-0.37	-0.27	-0.11	0.11	0.40	0.58	0.67	0.69	0.66
After-tax return to capital	4.73	0.26	0.33	0.42	0.51	0.61	0.38	0.20	0.05	-0.06

after-tax gross return to capital. The first model variant increases the coefficient of relative risk aversion,  $\gamma$ , from 1 to 5. This change has two important implications. First, utility is no longer additively separable between consumption and leisure which implies that the intertemporal marginal rate of substitution now depends not only on consumption but also leisure (hours of work). Second, the representative household will have a stronger utility-smoothing motive as  $\gamma$  increases.<sup>3</sup>

Table 8 summarizes the results for the U.S. data, the benchmark model, and the three variants considered in this subsection. The calibration procedure implies that average rate of return across model variants are identical. For now, concentrate on the “Risk Aversion” results. Increasing risk aversion raises the volatility of the return to capital both in absolute terms, and relative to the volatility of output. The model now captures roughly 80% of the relative volatility in the return to capital; the benchmark model captures 50%. For the most part, this improvement does not come at the cost of substantially worsening the model’s predictions for the real side of the economy. Indeed, the variability of both consumption and investment are closer to the data.

The second model variant considers Hansen (1985)–Rogerson (1988) indivisible labor. This variant operates more on the return to capital term in (5). In particular, Hansen showed that indivisible labor could substantially increase the volatility of hours worked. If the variability of capital is not much affected by the introduction of indivisible labor, then we might expect to see more volatility in the marginal product of capital, and so the return to capital; to see this, rewrite (5) as

$$1 = E_t \left\{ \left( \beta \frac{U_{c,t+1}}{U_{c,t}} \right) \left[ (1 - \tau_k) z_{t+1} \alpha \left( \frac{g^{t+1} h_{t+1}}{k_{t+1}} \right)^{1-\alpha} + 1 - \delta \right] \right\}. \quad (6)$$

Relative to the benchmark model, introducing indivisible labor increases the volatility of macroaggregates – just as in Hansen. While the variability of the return to capital increases – from 4.73 to 5.50 – its volatility relative to output is essentially unchanged.

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<sup>3</sup>To the extent that introducing habit persistence has effects similar to increasing risk aversion, this experiment is suggestive of the likely effects of introducing habit.

Table 8: Alternative Models and Parameterizations

	U.S.		Benchmark		Risk Aversion: $\gamma = 5$		Indivisible Labor		Home Production	
	SD	Corr.	SD	Corr.	SD	Corr.	SD	Corr.	SD	Corr.
Output	1.71	1.00	1.49	1.00	1.30	1.00	1.82	1.00	2.24	1.00
Consumption	0.86	0.79	0.70	0.96	0.80	1.00	0.81	0.95	0.95	0.98
Investment	4.17	0.69	7.24	0.98	4.82	0.99	9.36	0.97	191.47	0.14
Hours	1.70	0.81	0.63	0.97	0.38	1.00	1.09	0.97	1.31	0.99
Productivity	1.05	0.31	0.89	0.99	0.93	1.00	0.80	0.95	0.95	0.99
Capital	1.00	-0.18	0.54	0.40	0.38	0.28	0.68	0.41	1.33	0.97
Return to capital	11.49	0.30	4.73	0.61	6.98	0.42	5.50	0.63	4.14	0.57

The final variant introduces home production; see [Benhabib, Rogerson and Wright \(1991\)](#) and [Greenwood and Hercowitz \(1991\)](#). Home production is likely to operate primarily through the intertemporal marginal rate of substitution with general equilibrium effects on the marginal product of capital. Allowing agents another margin along which they can smooth utility – namely through home production – may make them more tolerant of fluctuations in market consumption, the object that appears in (5). Details of this model are left to the Appendix which also briefly discusses calibration of the home production model. In [Table 8](#), *market* variables are reported for the home production model. In many ways, the home production model is a bust. The volatility of (market) investment is two orders of magnitude too large relative to the data, and is only weakly procyclical. Papers that have successfully addressed the investment volatility issue include [Greenwood and Hercowitz \(1991\)](#), [Greenwood, Rogerson and Wright \(1995\)](#) and [Gomme, Kydland and Rupert \(2001\)](#). More pertinent to the focus of this paper, the home production model implies *lower* volatility (both absolute and relative to that of output) for the return to capital.

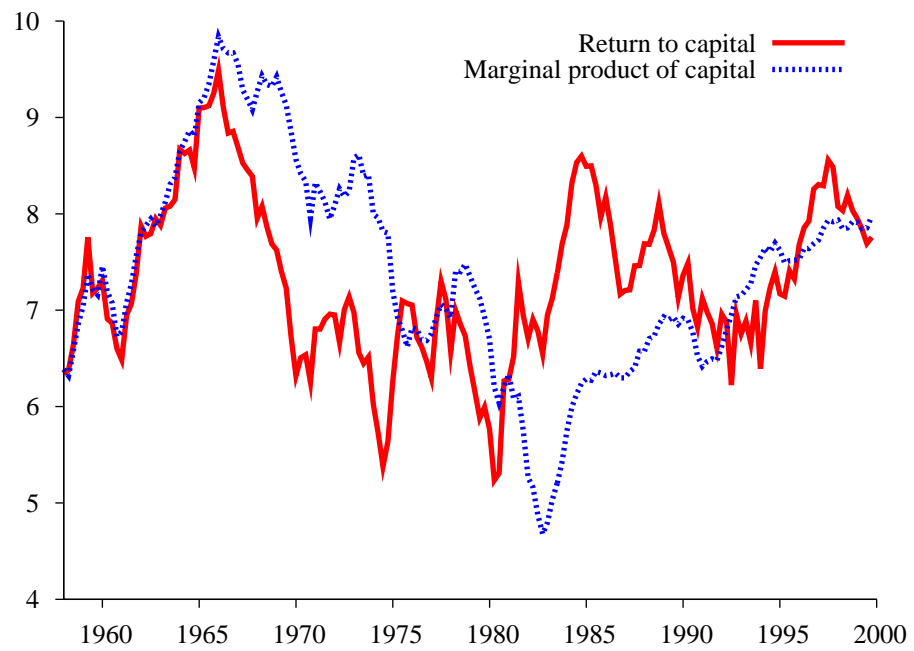
## 5 Conclusions

We constructed a time series for the after-tax return to capital and showed that its behavior is substantially different from the S&P500 returns. Our measure of return to capital is considerably smoother (by a factor of 28) and has a higher mean. The standard real business cycle model accounts for half of the volatility in the return to capital. We considered three variants of the standard model – high risk aversion, indivisible labor and home production. The high risk aversion model delivers  $\frac{4}{5}$  of the volatility in the return to capital, the indivisible labor model delivers 45% while the home production model less than 30%.

A natural question at this stage is whether models in the RBC class could ever deliver

the volatility in the rate of return to capital just by successfully delivering the aggregate quantities. One approach to answer this question is to examine the  $(1 - \tau_k)\alpha (y_t/k_t) + 1 - \delta$  time series in the data; i.e., hold fixed  $\tau_k$ ,  $\alpha$  and  $\delta$  as in the model and compute the after-tax marginal product of capital using data on output and capital stock. [Figure 2](#) illustrates this time series along with the after-tax rate of return to capital. The standard deviation of the after-tax marginal product of capital is 18.4% while the standard deviation of our measure of the rate of return to capital is 11.5%. A model that replicates the time series properties of output and capital stock could potentially generate more than sufficient volatility in the after-tax marginal product of capital to account for the volatility in the rate of return to capital. [Table 8](#) provides some insight into factors that are important for accounting for the volatility of the return to capital. Increasing the volatility of output and/or capital increases the variability of the return to capital as seen by comparing the benchmark and indivisible labor models. However, increasing the volatility of these macroaggregates is not sufficient; the home production model has much higher output and market capital stock variability, yet the volatility of the return to capital is lower than in the benchmark model. In the case of home production, the model also generates a very strong positive correlation between output and market capital, a factor that works against generating high volatility in the return to capital. By way of contrast, the data exhibits a small negative correlation between output and capital. To drive this point home, consider the high risk aversion model. In this case, the volatilities of output and capital are lower than in the benchmark model (factors that would tend to reduce the variability of the return to capital), and the correlation between output and capital is also lower (which tends to raise the volatility of the return to capital); the net result is higher variability in the return to capital.

Figure 2: Return to Capital and Marginal Product of Capital



## Appendix: Home Production

The market sector, denoted by the subscript  $M$ , produces output according to the technology

$$y_{Mt} = z_{Mt} k_{Mt}^{\alpha} (g^t h_{Mt})^{1-\alpha}, \quad (\text{A.1})$$

where  $y_M$  is the amount of output,  $k_M$  denotes the beginning of period capital stock,  $h_M$  denotes hours worked,  $g$  is the growth rate of labor-augmenting technical change, and  $z_M$  denotes the state of disembodied technical progress. Output in the market sector can be allocated between consumption goods and investment goods such that

$$c_{Mt} + i_{Mt} + i_{Ht} = y_{Mt},$$

where  $c_M$  denotes market consumption,  $i_M$  market investment, and  $i_H$  home investment.

The representative firm's problem is to choose  $k_{Mt}$  and  $h_{Mt}$  in order to

$$\max z_M k_{Mt}^{\alpha} (g^t h_{Mt})^{1-\alpha} - w_t h_{Mt} - r_t k_{Mt}$$

where  $w_t$  is the real wage rate, and  $r_t$  is the real rental rate on market capital.

Consumption goods in the home sector (denoted by  $H$  subscripts) use labor and home capital according to the technology

$$c_{Ht} = k_{Ht}^{\theta} (g^t h_{Ht})^{1-\theta}. \quad (\text{A.2})$$

Market and home capital evolve according to

$$k_{Mt+1} = (1 - \delta_M) k_{Mt} + i_{Mt} \quad (\text{A.3})$$

$$k_{Ht+1} = (1 - \delta_H) k_{Ht} + i_{Ht}. \quad (\text{A.4})$$

The representative household has preferences over market consumption,  $c_{Mt}$ , home consumption,  $c_{Ht}$ , market hours,  $h_{Mt}$ , and home hours,  $h_{Ht}$ , summarized by

$$E_0 \sum_{t=0}^{\infty} \beta^t U(c_{Mt}, c_{Ht}, h_{Mt}, h_{Ht}), \quad 0 < \beta < 1, \quad (\text{A.5})$$

where

$$U(c_M, c_H, h_M, h_H) = \begin{cases} \frac{[C(c_M, c_H)(1-h_M-h_H)^\omega]^{1-\gamma}}{1-\gamma} & \text{if } 0 < \gamma < 1 \text{ or } \gamma > 1, \\ \ln C(c_M, c_H) + \omega \ln(1-h_M-h_H) & \text{if } \gamma = 1, \end{cases} \quad (\text{A.6})$$

where  $C$  is the “aggregate” of market and home consumption, described by:

$$C(c_m, c_h) = \begin{cases} [\psi c_m^\xi + (1-\psi)c_h^\xi]^{1/\xi} & \text{if } \xi \in (-\infty, 0) \cup (0, 1) \\ c_m^\psi c_h^{1-\psi} & \text{if } \xi = 0. \end{cases} \quad (\text{A.7})$$

Implicit in (A.6) is an assumption that the individual’s time endowment is equal to one.

Given the initial conditions  $k_{M0}$  and  $k_{H0}$ , the representative agent’s problem is to choose  $\{c_{Mt}, c_{Ht}, h_{Mt}, h_{Ht}, k_{Mt+1}, k_{Ht+1}\}_{t=0}^\infty$  in order to maximize (A.5) subject to (A.2)–(A.4), (2), and

$$c_{Mt} + i_{Mt} + i_{Ht} = (1 - \tau_\ell)w_t h_{Mt} + (1 - \tau_k)r_t k_{Mt} + T_t.$$

where  $T_t$  is the transfer from the government in period  $t$ .

The government satisfies its budget constraint,

$$\tau_\ell w_t h_{Mt} + \tau_k r_t k_{Mt} = T_t$$

In steady state, the model must be consistent with long run averages observed in the U.S. data; for data details, see [Gomme and Rupert \(forthcoming\)](#). These long run averages are summarized in [Table 9](#). The first three of these long run averages directly determine the parameters  $\alpha$ ,  $\delta_M$  and  $\delta_H$ . The coefficient of relative risk aversion,  $\gamma$ , is set to one which implies logarithmic utility. The curvature parameter in the consumption aggregator,  $\xi$ , is set to 0.4 based on estimates by [McGrattan, Rogerson and Wright \(1997\)](#) and [Rupert, Rogerson and Wright \(1995\)](#). The remaining parameters,  $\beta$ ,  $\omega$ ,  $\psi$  and  $\theta$ , are set to match the remaining four long run averages in [Table 9](#). The parameter values are summarized in [Table 10](#). Finally, the properties of the stochastic technology process are as for the benchmark model.

Table 9: Long Run Averages for the Home Production Model

Observation	Value
Capital's share of market income	0.283
Depreciation of market capital (annual)	0.069113
Depreciation of home capital (annual)	0.059981
Market investment as a share of market output	0.1306
Home investment as a share of market output	0.1571
Market hours	0.255
Home hours	0.24

Table 10: Home Production Model Parameter Values

Parameter	Description	Value
$\alpha$	Capital's share of market income	0.283
$\delta_M$	Depreciation of market capital (quarterly)	0.0177
$\delta_H$	Depreciation of home capital (quarterly)	0.0153
$\gamma$	Coefficient of relative risk aversion	1
$\xi$	Curvature parameter in consumption aggregator	0.4
$\tau_k$	Capital income tax rate	0.2868
$\tau_\ell$	Labor income tax rate	0.2200
$\beta$	Discount factor	0.9882
$\omega$	Utility weight on leisure	0.7423
$\psi$	Parameter on market consumption in consumption aggregator	0.5274
$\theta$	Capital's share in home production	0.3249
$\rho$	Autoregressive parameter of technology shock	0.96405
$\sigma$	Standard deviation of innovation to technology shock	0.00818

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