

Heterogeneity and Aggregation in the Labor Market: Implications for Aggregate Preference Shifts*

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Abstract

The cyclical behavior of hours worked, wages, and consumption does not conform with the prediction of the representative agent with standard preferences. The residual in the intra-temporal first-order condition for commodity consumption and leisure is often viewed as a failure of labor-market clearing. We show that a simple heterogeneous-agent economy with incomplete markets and indivisible labor generates an aggregation error that looks much like the preference residual in the data. Our results caution against viewing the preference residual as a failure of labor-market clearing or a fundamental driving force of business cycles.

Keywords: Aggregation, Heterogeneity, Incomplete Market, Aggregate Preference Shifts

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1 Introduction

The equilibrium outcome of the representative-agent model with standard preferences is hard to reconcile with the joint behavior of aggregate hours worked, consumption, and wages over the business cycle (Barro and King, 1984; Mankiw, Rotemberg and Summers, 1989). The accounting method that uses the optimality condition for the choice between consumption and leisure measures a significant residual in preference (e.g., Hall, 1997). This is often viewed as a failure of the labor-market clearing.

In this paper, we show that a heterogeneous-agent economy with incomplete capital market and indivisible labor can generate an aggregation error that looks like a preference shock. Although there are no inherent preference shifts, in the face of aggregate technology shocks, the model generates an aggregation error that is comparable to the preference residual in the data: it is highly correlated with hours worked and as volatile as the cyclical component of hours. Our results caution against viewing the preference residual as a failure of labor-market clearing or a fundamental driving force of business cycles.

Our analysis quantitatively complements the theoretical work by Sheinkman and Weiss (1986) who show that capital-market incompleteness can lead to a stochastic term in aggregate preferences. It also complements Nakajima (2003) who derives aggregate preference shocks and the variation of TFP in a two-type households model with capacity utilization and government spending shocks. According to our model, however, an incomplete capital market alone cannot generate an aggregation error quantitatively comparable to the preference residual observed in the data. With divisible labor, hours are highly correlated across households in response to aggregate shocks, allowing for a fairly good aggregation. Indivisible labor alone cannot account for the preference residual in the data either. Entry and exit of workers with heterogeneous skill creates a compositional bias in aggregate wages and hours (Bils, 1985; Solon, Barsky and Parker, 1989). The compositional bias, however, has an impact mostly on the magnitudes, not the correlations. In the data, the preference residual arises not only because hours worked moves little relative to wages, but also

because it is not strongly correlated with the measured price of leisure. The preference residual is significantly magnified when incomplete capital market is combined with indivisible labor. The participation margin makes the aggregate labor supply more elastic; consumption fluctuates more over the business cycle as the household's expenditure depends on the employment status and current income; more importantly, the aggregate labor-supply elasticity is time-varying as the shape of reservation-wage distribution changes over time.

The paper is organized as follows. Section 2 briefly discusses the preference residual in the data. Section 3 lays out the model economy. In Section 4, we calibrate the model economy and compare the preference residual from the model to that in the data. In Section 5, we distinguish the roles of market incompleteness and indivisible labor by investigating the economies with and without the complete market and indivisible labor. Section 6 is the conclusion.

2 Preference Residual in Aggregate Data

One of the leading topics in macroeconomics is the identification of the fundamental driving forces behind economic fluctuations. Economists adopt accounting procedures that use aggregate time series data together with equilibrium conditions of a prototype model. A prominent example is Solow residual. Under the assumptions about market competition and the production function, shifts in technology are identified (e.g., Kydland and Prescott, 1982).¹ Likewise, the standard optimality condition on the choice between commodity consumption and leisure (together with the assumption that household efforts are paid for by their marginal product) identifies the preference residual (e.g., Hall, 1997). To illustrate, consider a representative agent who maximizes the utility under the competitive labor market:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln C_t - B \frac{H_t^{1+1/\gamma}}{1+1/\gamma} \right\},$$

¹The Solow residual is subject to specification errors due to, for example, imperfect competition, cyclical utilization, and aggregation across firms (e.g., Hall, 1987).

where β is the discount factor, C_t is consumption, and H_t is hours worked.² The parameter γ represents the compensated labor-supply elasticity and B is the utility parameter. Given the real wage rate W_t , hours worked and consumption satisfy the intra-temporal first-order condition (which is also referred to as Frisch labor-supply function):

$$BH_t^{1/\gamma} = \frac{W_t}{C_t}. \quad (1)$$

Figure 1 shows the cyclical components of total hours worked and two measures of marginal disutility from working according to (1) for U.S. for 1964:I-2003:II. Hours worked represents the total hours employed in the non-agricultural business sector. Consumption reflects the expenditure on nondurable goods and services. For the real wage rate, we use two different measures: labor productivity of non-agricultural business sector and real hourly earnings of production and non-supervisory workers.³ All series are detrended by the Hodrick-Prescott filter. hours worked often move in the opposite direction to its price, suggesting a serious departure from a stable labor-supply schedule. This is often viewed as a failure of labor-market clearing or existence of preference shocks.

Under the assumption that the aggregate labor-supply elasticity (γ) is 1, we compute the implied (or required) time series of preference residual (B) that accommodates the first-order condition (1). This elasticity is higher than a typical estimate in the micro data (e.g., MaCurdy, 1981), which is less than 0.5. Assuming an inelastic labor supply (a smaller value of γ) leads to a bigger residual (e.g., $\gamma = 1/1.7$ in Hall (1997)). Conversely, elastic labor supply produces a smaller residual. Nevertheless, a particular choice of aggregate elasticity does not alter the conclusion of the paper. Figure 2 shows the time series of preference residual along with the hours worked. It is highly correlated with labor supply and its volatility is in the same order of magnitude as hours worked, which makes it often listed as a candidate driving force of economic fluctuations (Hall, 1997; Chari, Kehoe and McGrattan, 2002). A strong interpretation of the residual would be shifts in marginal

²While this form of utility is popular in both business cycle analysis and empirical labor supply literature, time non-separability does not account for the joint behavior of hours, wages and consumption in the data (Mankiw et al., 1989).

³While the real hourly earning is more relevant measure, the wage data at quarterly frequency is limited to those of production and non-supervisory workers only. Following Hall (1997), we use labor productivity for the rest of the paper and the main result does not depend on the choice of wage measure.

rate of substitution between commodity consumption and leisure at the aggregate level. A weak interpretation would be labor-market frictions, the extent to which the labor market deviates from a competitive equilibrium.⁴ In the next section, we present a model economy in which the preference residual arises as an aggregate error.

3 The Model

There is a continuum (measure one) of workers who have identical preferences but different productivity. Individual productivity varies exogenously according to a stochastic process with a transition probability distribution function $\pi_x(x'|x) = \Pr(x_{t+1} \leq x' | x_t = x)$. A worker maximizes his utility over consumption c_t and hours worked h_t :

$$\max_{\{c_t, h_t\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln c_t - B \frac{h_t^{1+1/\gamma}}{1+1/\gamma} \right\} \quad (2)$$

subject to

$$a_{t+1} = w_t x_t h_t + (1 + r_t) a_t - c_t. \quad (3)$$

Workers trade claims for physical capital, a_t , which yields the rate of return r_t and depreciates at the rate δ . The capital market is incomplete. Physical capital is the only asset available to workers who face a borrowing constraint: $a_t \geq \bar{a}$ for all t . Following Hansen (1985) and Rogerson (1988), we abstract from the intensive margin and assume that labor supply is indivisible; i.e., h_t takes either zero or $\bar{h} (< 1)$. If employed, a worker supplies \bar{h} unit of labor and earns $w_t x_t \bar{h}$, where w_t is wage rate per effective unit of labor.⁵

The representative firm produces output according to a constant returns Cobb-Douglas tech-

⁴Two important premises in the calculation of the preference residual are: competitive labor market and aggregation. While we focus on the latter only, this does not necessarily reflect our view on the importance of non-competitive nature in the labor market. We maintain the competitive labor market to highlight the aggregation problem.

⁵In general, the labor supply decision operates on both the extensive and the intensive margins. However, it is rare for workers to be allowed to choose completely flexible work schedules or to supply a tiny amount of hours. Furthermore, it is well known that the variation in the number of employees is the dominant source of fluctuations in total hours worked (e.g., Heckman, 1984).

nology in capital, K_t , and efficiency units of labor, L_t :⁶

$$Y_t = F(L_t, K_t, \lambda_t) = \lambda_t L_t^\alpha K_t^{1-\alpha},$$

where λ_t is the aggregate productivity shock with a transition probability distribution function $\pi_\lambda(\lambda'|\lambda) = \Pr(\lambda_{t+1} \leq \lambda' | \lambda_t = \lambda)$.⁷

The value function for an employed worker, denoted by V^E , is:

$$V^E(a, x; \lambda, \mu) = \max_{a' \in \mathcal{A}} \left\{ \ln c - B \frac{\bar{h}^{1+1/\gamma}}{1+1/\gamma} + \beta E \left[\max \{ V^E(a', x'; \lambda', \mu'), V^N(a', x'; \lambda', \mu') \} | x, \lambda \right] \right\} \quad (4)$$

subject to

$$c = wx\bar{h} + (1+r)a - a',$$

$$a' \geq \bar{a},$$

$$\mu' = \mathbf{T}(\lambda, \mu),$$

where \mathbf{T} denotes a transition operator that defines the law of motion for the distribution of workers $\mu(a, x)$.⁸ The value function for a non-employed worker, denoted by $V^N(a, x; \lambda, \mu)$, is defined similarly with $h = 0$. Then, the labor-supply decision is characterized by:

$$V(a, x; \lambda, \mu) = \max_{h \in \{0, \bar{h}\}} \{ V^E(a, x; \lambda, \mu), V^N(a, x; \lambda, \mu) \}.$$

Equilibrium consists of a set of value functions, $\{V^E(a, x; \lambda, \mu), V^N(a, x; \lambda, \mu), V(a, x; \lambda, \mu)\}$, a set of decision rules for consumption, asset holdings, and labor supply, $\{c(a, x; \lambda, \mu), a'(a, x; \lambda, \mu), h(a, x; \lambda, \mu)\}$, aggregate inputs, $\{K(\lambda, \mu), L(\lambda, \mu)\}$, factor prices, $\{w(\lambda, \mu), r(\lambda, \mu)\}$, and a law of motion for the distribution $\mu' = \mathbf{T}(\lambda, \mu)$ such that:

⁶This implicitly assumes that workers are perfect substitutes for each other. While this assumption abstracts from reality, it greatly simplifies the labor-market equilibrium.

⁷In this model economy, technology shock is the only aggregate shock. This does not necessarily reflect our view on the source of business cycles. As we would like to show that the preference residual contains a significant specification error rather than true shifts in preferences, we intentionally exclude shocks that may shift the labor-supply schedule itself (e.g., shifts in government spending or changes in income tax rate) here.

⁸Let \mathcal{A} and \mathcal{X} denote sets of all possible realizations of a and x , respectively. The measure $\mu(a, x)$ is defined over a σ -algebra of $\mathcal{A} \times \mathcal{X}$.

1. Individuals optimize:

Given $w(\lambda, \mu)$ and $r(\lambda, \mu)$, the individual decision rules $c(a, x; \lambda, \mu)$, $a'(a, x; \lambda, \mu)$, and $h(a, x; \lambda, \mu)$ solve $V^E(a, x; \lambda, \mu)$, $V^N(a, x; \lambda, \mu)$, and $V(a, x; \lambda, \mu)$

2. The representative firm maximizes profits:

$$w(\lambda, \mu) = F_1(L(\lambda, \mu), K(\lambda, \mu), \lambda) \quad (5)$$

$$r(\lambda, \mu) = F_2(L(\lambda, \mu), K(\lambda, \mu), \lambda) - \delta \quad (6)$$

for all (λ, μ) .

3. The goods market clears:

$$\int \{a'(a, x; \lambda, \mu) + c(a, x; \lambda, \mu)\} d\mu = F(L(\lambda, \mu), K(\lambda, \mu), \lambda) + (1 - \delta)K \quad (7)$$

for all (λ, μ) .

4. Factor markets clear:

$$L(\lambda, \mu) = \int xh(a, x; \lambda, \mu) d\mu \quad (8)$$

$$K(\lambda, \mu) = \int ad\mu \quad (9)$$

for all (λ, μ) .

5. Individual and aggregate behaviors are consistent:

$$\mu'(A^0, X^0) = \int_{A^0, X^0} \left\{ \int_{\mathcal{A}, \mathcal{X}} \mathbf{1}_{a'=a'(a, x; \lambda, \mu)} d\pi_x(x'|x) d\mu \right\} da' dx' \quad (10)$$

for all $A^0 \subset \mathcal{A}$ and $X^0 \subset \mathcal{X}$.

4 Quantitative Analysis

4.1 Calibration

We briefly explain the choice of the model parameters. The details can be found in Chang and Kim (2003) in which a similar model economy is used to study the mapping from individual to

aggregate labor-supply elasticities. The unit of time is a quarter. We assume that x follows an AR(1) process: $\ln x' = \rho_x \ln x + \varepsilon_x$, where $\varepsilon_x \sim N(0, \sigma_x^2)$. As we view x reflecting a broad measure of earnings ability in the market, individual wages from the PSID for 1971-1992 are used to estimate the stochastic process of x . We set $\rho_x = 0.95$ and $\sigma_x = 0.225$.⁹

Other parameters are in accordance with the business cycle analysis and empirical labor supply literature. A working individual spends one-third of discretionary time: $\bar{h} = 1/3$. The individual compensated labor-supply elasticity of hours, γ , is 0.4. The labor share of output, α , is 0.64, and the depreciation rate, δ , is 2.5 percent. We search for the weight parameter on leisure, B , such that the steady state employment rate is 60 percent, the average from the CPS for 1967:II-2000:IV. The discount factor β is chosen so that the quarterly rate of return to capital is 1 percent. Aggregate productivity shock, λ_t , follows an AR(1) process: $\ln \lambda' = \rho_\lambda \ln \lambda + \varepsilon_\lambda$, where $\varepsilon_\lambda \sim N(0, \sigma_\lambda^2)$. We set $\rho_\lambda = 0.95$ and $\sigma_\lambda = 0.007$ following Kydland and Prescott (1982). Table 1 summarizes the parameter values of the benchmark economy.

4.2 Cross-sectional Earnings and Wealth Distribution

As we investigate the aggregation issue, it is desirable for the model economy to possess a reasonable heterogeneity. We compare the cross-sectional earnings and wealth—two important (observable) dimensions of heterogeneity in the labor market—between the model and the data.

Table 2 summarizes the detailed information on wealth and earnings from the PSID and the model. Family wealth in the PSID (1984 survey) reflects the net worth of house, other real estate, vehicles, farms and businesses owned, stocks, bonds, cash accounts, and other assets. For each quintile group of wealth distribution, we calculate the wealth share, the ratio of group average to economy-wide average, and the earnings share.

Both in the data and model, the poorest 20 percent of the wealth distribution owns virtually nothing. In fact, households in the first quintile of the wealth distribution are in debt both in the

⁹In Chang and Kim (2003) we report various estimates for ρ_x and σ_x , controlling for selection bias and individual effects. The aggregate time series behavior of consumption, hours worked, and wages—which is our primary interest in this paper—is not sensitive to the values of ρ_x and σ_x we considered.

model and data. On the contrary, households in the 4th and 5th quintile of the PSID own 18.74 and 76.22 percent of total wealth, respectively. According to the model, they own 24.48 and 66.31 percent, respectively. The average wealth of the 4th and 5th quintile are, respectively, 0.93 and 3.81 times larger than that of a typical household, while these ratios are 1.22 and 3.33 according to our model. The 4th and 5th quintile groups of the wealth distribution earn, respectively, 24.21 and 38.23 percent of total earnings in the PSID. The corresponding groups earn 23.44 and 30.39 percent, respectively, in the model.

Overall, the wealth distribution is more skewed in the data. In particular, the model fails to match the highly concentrated wealth in the right tail of the distribution. About half of the total wealth is held by the top 5 percent of the population (not shown in Table 2). In our model, only 20 percent of the total wealth is held by them. However, our primary objective is not to explain the behavior of the top 1 or 5 percent of the population. We argue that the model economy possesses reasonable heterogeneity to study aggregation effects in the labor market.

4.3 Cyclical Properties of the Model

We numerically solve the equilibrium of the model using the “bounded rationality” method of Krusell and Smith (1998), and generate the aggregate time series through simulations.¹⁰

Table 3 shows the volatility of key aggregate variables from our model economy. In the face of aggregate productivity shocks whose stochastic process resembles that of the U.S. TFP, the model-output exhibits the volatility of 1.30, about two thirds of actual-output volatility. This is similar to the findings based on the standard representative-agent models (e.g., Kydland and Prescott, 1982). Other statistics are also similar to those from the standard models: consumption is about half as volatile as output and investment is about three to four times as volatile as output.

A distinguishing feature of our model is the labor market. The (relative) volatility of hours and productivity are very close to those in the data, which is hard to achieve in a standard model

¹⁰The model generated aggregated time series is based on the individual choices of 200,000 agents over 3,500 periods.

unless unreasonably high labor-supply elasticity is assumed. The volatility of hours relative to output is 0.82 (0.85 in the data), and the volatility of labor productivity relative to output is 0.54 (0.50 in the data). This success is mostly due to the composition effect generated by entry and exit of workers with heterogeneous productivity. On average, less-productive workers participate in the labor market during expansions and exit during contractions. The measured hours are more volatile than the hours in effective units and the aggregate wage is less volatile than the individual wages. When we measure the hours worked in effective units, it is about half as volatile as output (0.53), similar to the outcome of the representative-agent model with standard preferences.

Table 4 shows the correlations. The correlations among output, consumption, and investment are higher than those in the data, a feature common in the standard RBC models. However, the correlations of hours and labor productivity with output are 0.85 and 0.55, respectively, close to those in the data. In particular, hours and labor productivity exhibit virtually no correlation (0.04) as in the data (0.03). This is surprising because a near-zero correlation between hours and labor productivity has been noted as one of the most salient failures of the RBC models.

4.4 Preference Residual from the Model

If we were to account for the model-generated aggregate time series of hours, wages, and consumption by a competitive equilibrium of a representative agent, we face the same problem: hours worked and marginal disutility from working do not co-move. To illustrate, we compute the preference residual from the model-generated aggregate time series.

Figure 3 shows total hours worked and the preference residual from the model (under the assumption that the labor supply elasticity is 1 as we did with the actual data). In terms of the second moments of Hodrick-Prescott filtered data, the residual from the model exhibits similar stochastic properties of those from the data. The standard deviation of the residual relative to output in the model is 1.15 (1.23 in the data). In absolute terms, the residual in the model is about two-thirds as volatile as those in the data. The correlation between the residual and total hours worked is -0.93 (-0.92 in the data). The correlation between hours and measured marginal

disutility of working (W/C) is -0.53, identical to the data.

Despite there being no inherent preference shifts, (in the face of aggregate technology shocks) the model generates aggregation error that looks much like the preference residual in the data. Our results caution against viewing the preference residual as the fundamental driving force of business cycles, as well as to the view that the residual reflects a failure of labor-market clearing.

5 Roles of Incomplete Market and Indivisible Labor

The residual in our model stems from capital market incompleteness and labor indivisibility. To investigate the marginal contributions of each, we consider three additional model economies. For comparison, we refer to the benchmark economy as HII which stands for “Heterogeneity-Incomplete Market-Indivisible Labor.”

5.1 Alternative Model Specifications

Heterogeneity + Complete Market + Indivisible Labor (HCI) The second model we consider allows for complete capital markets but maintains indivisible labor: “Heterogeneity-Complete Market-Indivisible Labor” (HCI). Thanks to perfect risk sharing, agents enjoy the same level of consumption regardless of their employment status, productivity, and asset holdings.¹¹

Equilibrium of this economy is identical to the allocation by the social planner who maximizes the weighted utility of the population. The planner chooses the sequence of consumption $\{C_t\}_{t=0}^{\infty}$ and the cut-off productivity $\{x_t^*\}_{t=0}^{\infty}$ for labor-market participation. For an efficient allocation, the planner assigns workers who have comparative advantage in the market (more productive workers) to working. If a worker’s productivity is above x_t^* , he supplies \bar{h} hours of labor.

The planner’s value function in the complete market, $V^C(K, \lambda)$, and the decision rules for

¹¹The distribution of workers is no longer a state variable in the individual optimization problem. Moreover, due to the ergodicity of the stochastic process for idiosyncratic productivity, the cross-sectional distribution of workers is always stationary.

consumption, $C(K, \lambda)$, and cut-off productivity, $x^*(K, \lambda)$, satisfy the following Bellman equation:

$$V^C(K, \lambda) = \max_{C, x^*} \left\{ \log C - B \frac{\bar{h}^{1+1/\gamma}}{1 + 1/\gamma} \int_{x_t^*}^{\infty} \phi(x) dx + \beta E \left[V^C(K', \lambda') | \lambda \right] \right\} \quad (11)$$

subject to

$$K' = F(K, L, \lambda) + (1 - \delta)K - C, \quad (12)$$

where $L = \bar{h} \int_{x_t^*}^{\infty} x \phi(x) dx$ is the aggregate efficiency unit of labor, and $\phi(x)$ is the productivity distribution of workers. The planner chooses the cut-off productivity x^* so that:

$$\frac{1}{C} F_L(K, L, \lambda) \bar{h} x^* \phi(x^*) = B \frac{\bar{h}^{1+1/\gamma}}{1 + 1/\gamma} \phi(x^*). \quad (13)$$

The left-hand side is the (society's) utility gain from assigning the marginal worker to production. There are $\phi(x^*)$ number of workers with productivity x^* in the economy. Each of them supplies $\bar{h}x^*$ units of effective labor and the marginal product of labor is F_L . The right-hand side represents the disutility incurred by those workers. The key point here is that, under complete markets, the first-order condition for the choice between hours and consumption is well-defined in effective units even at the aggregate level. This is important because under this environment the preference residual would reflect the mis-specification in the aggregate labor-supply elasticity only. This is discussed in detail in section 5.2.

Heterogeneity + Incomplete Market + Divisible Labor (HID) The third model economy we consider allows for divisible labor supply, but capital markets are incomplete: “Heterogeneity-Incomplete Market-Divisible Labor (HID)”. The equilibrium of this economy can be defined similarly to that of HII in Section 3—equations (5) through (10)—with the worker's value function with divisible labor, $V^D(a, x; \lambda, \mu)$:

$$V^D(a, x; \lambda, \mu) = \max_{a' \in \mathcal{A}, h \in (0,1)} \left\{ \ln c - B \frac{h^{1+1/\gamma}}{1 + 1/\gamma} + \beta E \left[V^D(a', x'; \lambda', \mu') | x, \lambda \right] \right\} \quad (14)$$

subject to

$$c = wxh + (1 + r)a - a',$$

$$a' \geq \bar{a},$$

$$\mu' = \mathbf{T}(\lambda, \mu).$$

Representative-Agent Model (RA) The last model we consider is “Representative-Agent (RA)” model. The value function of the representative agent, $V^R(K, \lambda)$, is:

$$V^R(K; \lambda) = \max_{C, H} \left\{ \ln C - B \frac{H^{1+1/\gamma}}{1+1/\gamma} + \beta E \left[V^R(a', x'; \lambda', \mu') | x, \lambda \right] \right\} \quad (15)$$

subject to

$$K' = F(K, H, z) + (1 - \delta)K - C. \quad (16)$$

5.2 Comparison of Four Model Economies

Except for β and B , the same parameter values are used across the models. In the RA model, β is 0.99 and B is chosen so that steady-state hours worked is the same as the aggregate hours in the benchmark economy, which is 0.2 ($= \bar{h} \times 60\%$). For HCI, β is 0.99 and B is chosen to be consistent with 60% employment along with $\bar{h} = 1/3$.¹² For HID, β and B are jointly searched to be consistent with average hours of 0.2 and the interest rate of 1% in steady state. The equilibrium of the HCI economy is solved by the Parameterized Expectation Algorithm of Marcet and Lorenzoni (1999). The equilibrium of HID is solved by the “bounded rationality” method. The equilibrium of RA is solved by a value function iteration.

The preference residuals are computed using the aggregate labor-supply elasticity of 0.4 for divisible-labor economies (RA and HID), which is the same as individual elasticity. When labor supply is indivisible the aggregate labor-supply elasticity can be very different from the individual elasticity. In the complete market economy (HCI), the aggregate labor supply is governed by (13); whereas, in the incomplete market economy (HII), it depends on the shape of reservation-wage distribution. We compute the residuals assuming the aggregate elasticity of 1 for HII and HCI

¹²Specifically, we find the steady-state cut-off productivity, x^* , from the 60 percentile of individual productivity distribution, $\phi(x)$: $\int_{x^*}^{\infty} x\phi(x)dx = 0.6$ where $\phi(x)$ is log-normal distribution with the standard deviation in the benchmark model. Then, find B that satisfies the labor supply equation, (13).

for two reasons. It allows for a direct comparison with the residual from the data in section 2. According to our earlier study on the mapping from individual to aggregate labor supply (Chang and Kim, 2003), a model economy similar to HII exhibits the aggregate labor-supply elasticity around 1 in the steady state. Nevertheless, a particular choice of aggregate elasticity does not alter the main conclusion of the paper.

Figure 4 shows the sample paths (percentage deviations from the steady states) of the preference residuals from the models. The sample paths are comparable to each other because all model economies are subject to the identical sequence of aggregate productivity shocks. There is no preference residual in RA, as expected. The residual in HID represents the aggregation error due to incomplete markets only. The residual in HCI reflects the compositional bias in aggregate hours and wages. Apparently, these residuals are not large enough to account for the preference residual in the data. The volatilities of the residual relative to output are 0.1 for HID and 0.2 for HCI, which are, respectively, only one tenth and one sixth of that in the data (1.23).

Capital-market incompleteness alone does not generate a large aggregation error. With divisible labor, in response to aggregate productivity shocks, hours are highly correlated across households, allowing for a fairly precise aggregation. Indivisible labor alone cannot account for the preference residual in the data either. In the presence of the heterogeneous workforce, indivisible labor creates the compositional bias in aggregate hours and wages. The low-wage and less-skilled workers enter the labor market during expansions and exit during recessions, making the aggregate hours more volatile (than the effective unit of hours) and the aggregate wages less volatile (than individual wages).¹³ The compositional bias, however, has an impact mostly on the volatilities, not on the correlations. In fact, if we assume aggregate labor-supply elasticity of 1.71 in HCI, there is virtually no preference residual. In other words, the preference residual in HCI reflects the

¹³Bils (1985) and Solon et al. (1995), based on the individual panel data, find that aggregate wages are less cyclical than individual wages. Hansen (1993) computes the effective unit of hours based on worker characteristics from the CPS. He finds that while the effective unit of hours adjusted for quality exhibits a bigger volatility, such adjustment does not change the cyclical property of hours significantly. Estimating the quality-adjusted hours is not easy in practice because observed characteristics account for only a fraction of worker's productivity. For example, R^2 of cross-sectional wage regression is usually well below 0.4.

mis-specification error in aggregate labor-supply elasticity (due to composition bias in hours and wages) only. However, in the data (as well as in HII), we find the preference residual regardless of aggregate labor-supply elasticity. The residual arises not only because wages (more exactly, wage-consumption ratio) move little relative to hours worked, but also because they are not strongly correlated with hours over the business cycle.

The preference residual arises because aggregate hours move more relative to the measured marginal disutility of working. With $\gamma = 1$, the residual arises when aggregate hours and consumption fluctuate more relative to aggregate wages (e.g., $B_t = \frac{W_t}{C_t H_t}$). We compare the fluctuations of aggregate hours, wages, and consumption across the models. Figure 5 shows total hours worked (percentage deviations from the steady states). Hours worked in HID move similarly to those in RA, whereas total hours worked in indivisible labor economies (HII and HCI) fluctuate much more than those in RA. This suggests that indivisible labor is more important than incomplete markets for the volatility of hours worked. Hours worked fluctuate more in HII than they do in HCI. Under incomplete markets, high-skilled workers (as well as the low-skilled) perform intertemporal substitution in labor-market participation; whereas, under complete markets, only workers at the margin—whose productivity is around x^* in (13)—enter and exit the labor market in response to shifts in aggregate productivity. This can be seen more clearly when we measure the hours of work in effective units (Figure 6). The effective unit of hours is more volatile in HII than it is in HCI. Note also that, despite indivisible labor, the cyclical behavior of the effective unit of hours in HCI is identical to that in RA. Figure 7 shows aggregate wages across the models. As the compositional bias works the other way around here, wages fluctuate less in the indivisible labor economies (HII and HCI) than they do in divisible labor economies (HID and RA).

Figure 8 shows aggregate consumptions. Thanks to perfect risk sharing, consumption of HCI is identical to that of RA whereas consumption of HID is very close to that of RA. Aggregate consumption (as well as hours) fluctuates the most in HII. Under incomplete markets, household consumption depends on the current income—in particular, employment status—as well as wealth

of the household. According to the PSID, the household’s annual expenditure on food changes by 8% on average when the household head’s employment status changes from previous year. Considering a relatively flat Engel curve for food expenditure (e.g., Bils and Klenow, 1998), the employment effect would be bigger for total consumption. According to the annual panel data constructed from HII model, annual consumption changes by 14% on average when the agent’s employment status changes from previous year.¹⁴ In sum, volatile consumption, combined with smooth wages, makes the measured marginal disutility of working (W/C) moves little relative to the hours worked in HII model, creating a larger preference residual.

Finally, the aggregate labor-supply curve depends on the shape of reservation-wage distribution which, in turn, depends on the cross-sectional wealth distribution. As the wealth distribution of the economy changes, the response of aggregate labor supply and consumption varies over time. Figure 9 shows the sample path of summary statistics (mean, standard deviation, skewness, and kurtosis) of the asset distribution from HII. Although the mapping from asset distribution to reservation-wage distribution is complicated, a significant variation in these statistics suggests that aggregate labor-supply elasticity is not time-invariant. As a result, hours of work is not strongly correlated with wages in HII at aggregate level, whereas the correlation coefficients between aggregate hours and wages are, .97, .95, and .93 in RA, HID, and HCI, respectively.

Confronted with the inability of the standard equilibrium model to account for the joint behavior of aggregate hours worked, wages, and consumption, Mankiw et al. (1985) proposed four hypotheses: (1) measurement errors (2) aggregation (3) time-varying preference (4) failure of market clearing. While it is most plausible that all of these have contributed to the measured preference residual, our analysis sheds some lights on these hypotheses: measurement errors (1) due to com-

¹⁴The PSID panel data we use consists of 9 years (1979-1987) of annual expenditure on foods and household head’s employment data, yielding 17,850 person-year observations. The above estimate refers to $\hat{\beta}$ in the following regression: $\Delta \log c_{i,t} = \hat{\beta} \Delta d_{i,t} + \delta \mathbf{Z}_{i,t} + \epsilon_{i,t}$ where $c_{i,t}$ denotes the food consumption of the household i in year t and $d_{i,t}$ denotes the dummy variable for the employment status of the household head: $d_{i,t} = 1$ if the household head worked at least 500 hours during the year; $d_{i,t} = 0$ otherwise. $\mathbf{Z}_{i,t}$ denotes the control variables for household characteristics (age and years of schooling of the household head and the change in family size) and aggregate effects (year dummies). When the regression is performed separately for male and female household heads, $\hat{\beta}$ is 5% and 15%, respectively. We run the identical regression for the model-based annual panel data constructed from the simulated quarterly data of 10,000 agents for 30 years. $d_{i,t} = 1$ if the agent worked at least one quarter of the year.

position effect is not enough; (2) can be mis-interpreted as (3); the residual does not necessarily reflect (4).

6 Summary

The cyclical behavior of aggregate hours worked, wages, and consumption is hard to reconcile with the equilibrium outcome of the representative-agent model with standard preference. The accounting method that uses aggregate time series, together with the optimality condition, measures a significant residual in preference. We show that a heterogeneous-agent economy with incomplete capital markets and indivisible labor can generate an aggregation error which is quantitatively comparable to the preference residual in the data. Indivisible labor makes the aggregate labor supply elastic; consumption fluctuates more over the business cycle as the household's expenditure depends on the current income and employment; more importantly, the aggregate labor-supply elasticity is not time-invariant as the reservation-wage distribution changes over the business cycle. Our results caution against viewing the residual as a fundamental driving force or a failure of labor-market clearing.

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Table 1: Parameters of the Benchmark Model Economy

Parameter	Description
$\alpha = 0.64$	Labor share in production function
$\beta = 0.979852$	Discount factor
$\gamma = 0.4$	Labor-supply elasticity
$B = 170.39$	Utility parameter
$\bar{h} = 1/3$	Labor supply if working
$\bar{a} = -2.0$	Borrowing constraint
$\rho_x = 0.95$	Persistence of idiosyncratic productivity shock
$\sigma_x = 0.225$	Standard deviation of innovation to idiosyncratic productivity
$\rho_\lambda = 0.95$	Persistence of aggregate productivity shock
$\sigma_\lambda = 0.007$	Standard deviation of innovation to aggregate productivity

Table 2: Characteristics of Wealth Distribution

	Quintile					Total
	1st	2nd	3rd	4th	5th	
<u>PSID</u>						
Share of wealth	-0.52	0.50	5.06	18.74	76.22	100
Group average/population average	-0.02	0.03	0.25	0.93	3.81	1
Share of earnings	7.51	11.31	18.72	24.21	38.23	100
<u>Model</u>						
Share of wealth	-2.68	1.78	10.11	24.48	66.31	100
Group average/population average	-0.13	0.09	0.51	1.22	3.33	1
Share of earnings	10.79	15.94	19.43	23.44	30.39	100

Note: The PSID statistics reflect the family wealth and earnings from the 1984 survey.

Table 3: Volatilities of Aggregate Variables

Variable	Data	Model
σ_Y	2.04	1.30
σ_C/σ_Y	0.42	0.39
σ_I/σ_Y	3.59	3.02
σ_H/σ_Y	0.85	0.82
σ_L/σ_Y	–	0.53
σ_W/σ_Y	0.50	0.54
$\sigma_{W/C}/\sigma_Y$	0.55	0.48
σ_B/σ_Y	1.23	1.15

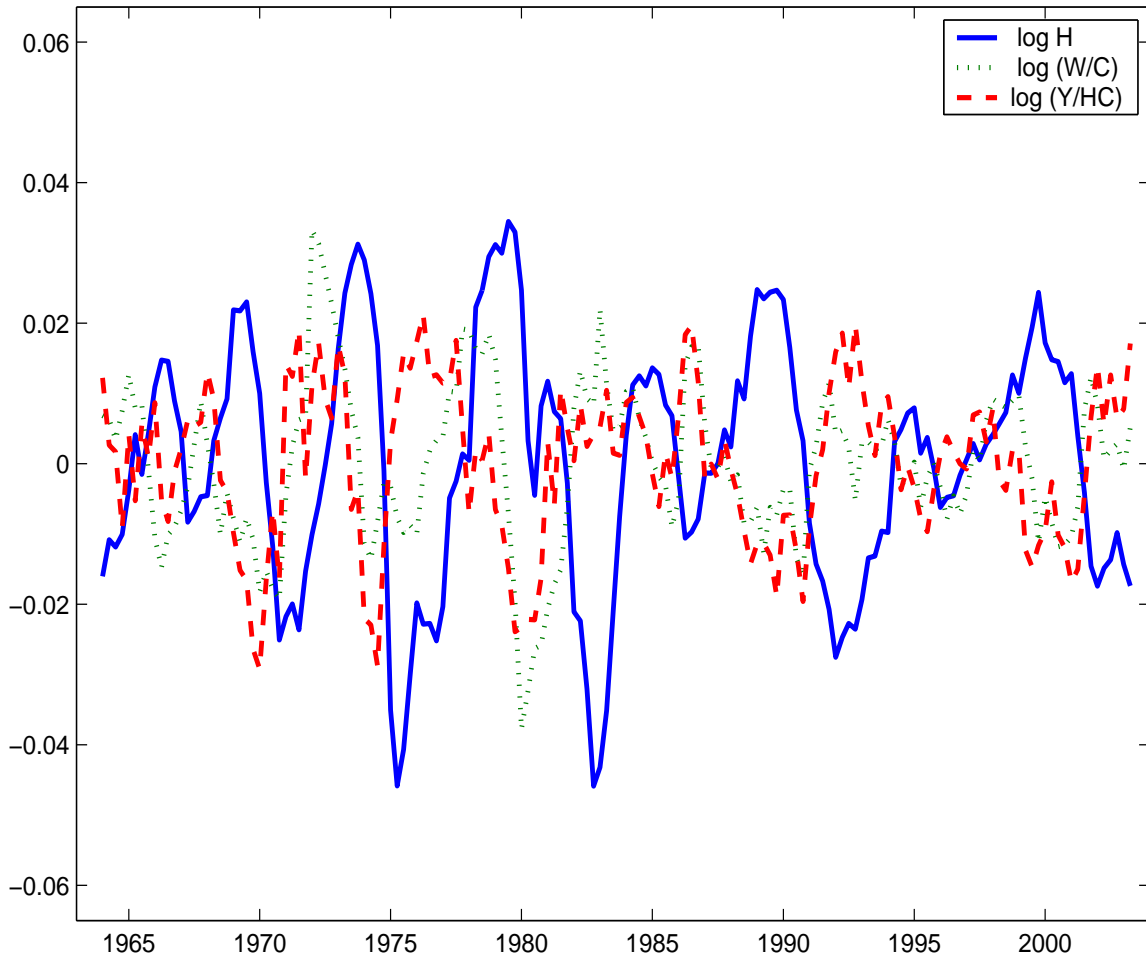
Note: All variables are logged and de-trended by the H-P filter. The volatility of output is measured by its standard deviation, and those of all other variables are by the relative standard deviations to output. The variable L denotes the effective unit of hours.

Table 4: Correlations of Aggregate Variables

Variable	Data	Model
$cor(Y, C)$	0.77	0.84
$cor(Y, I)$	0.88	0.98
$cor(Y, H)$	0.87	0.85
$cor(Y, L)$	–	0.90
$cor(Y, W)$	0.52	0.55
$cor(H, W)$	0.03	0.04
$cor(H, W/C)$	-0.53	-0.53
$cor(B, H)$	-0.92	-0.93
$cor(B, Y)$	-0.64	-0.62

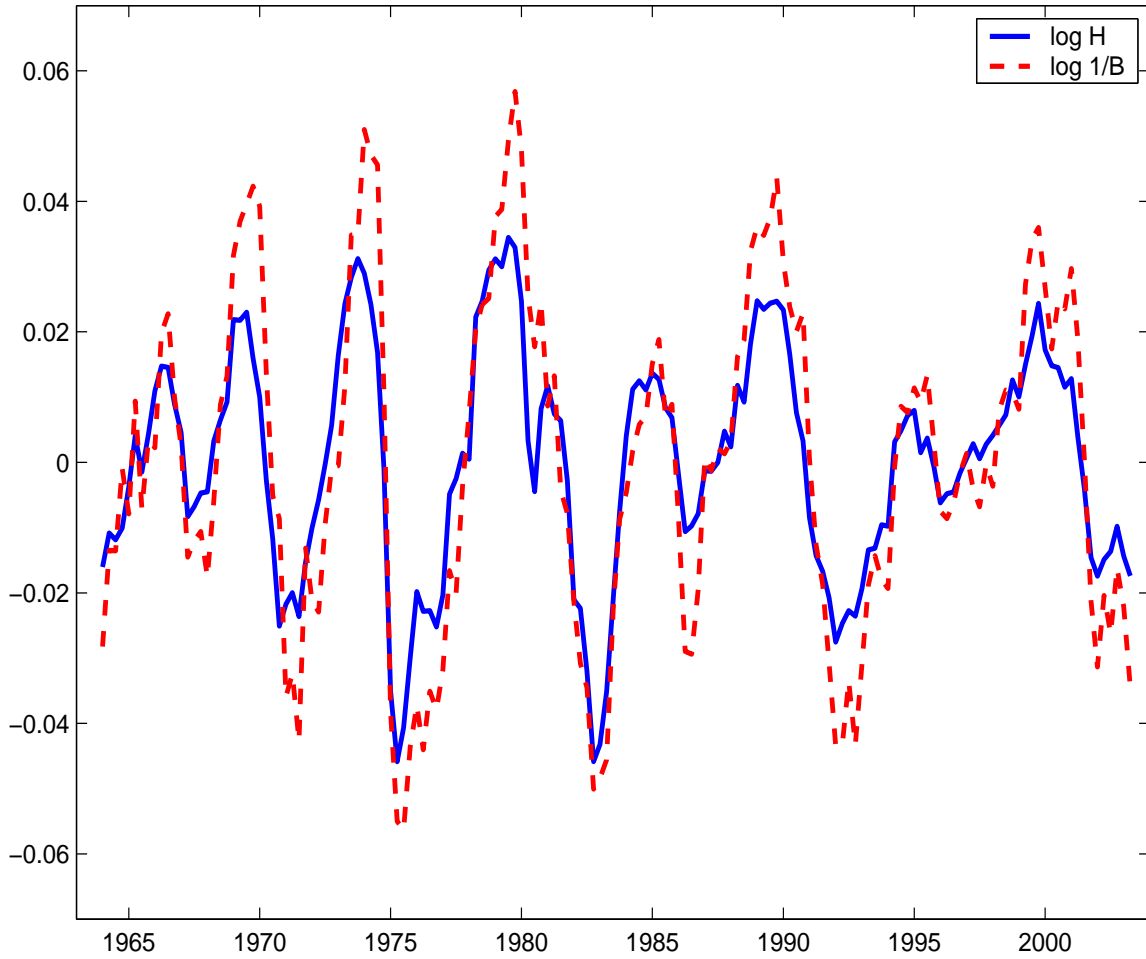
Note: See the note of Table 3 for variable descriptions.

Figure 1: Cyclical Components of Total Hours and Marginal Disutility from Working



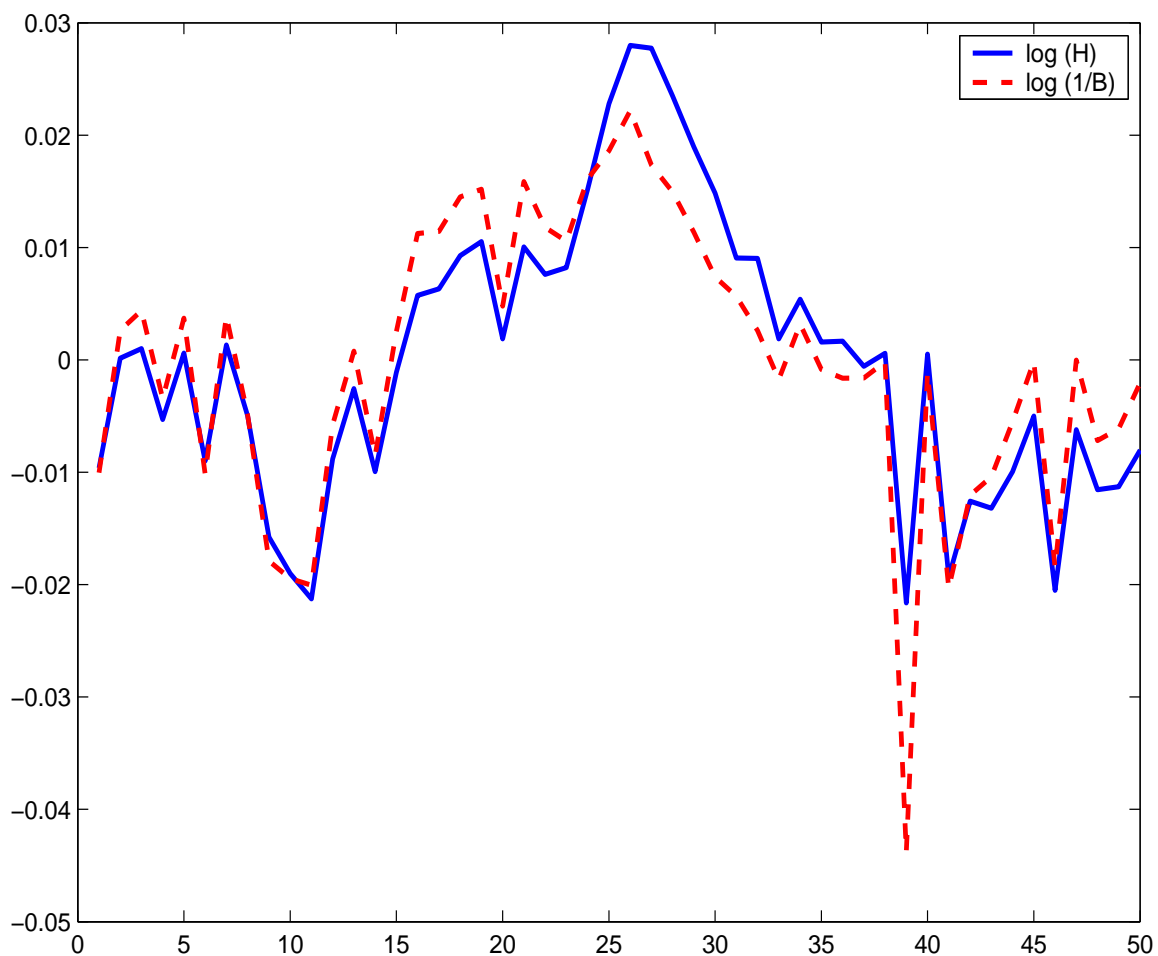
Note: Output and hours worked represent the non-agricultural private sector. Wage is real hourly earnings for non-supervisory and production workers. Consumption reflects expenditure on non-durable goods and services.

Figure 2: Cyclical Components of Hours and Preference Residuals for U.S.



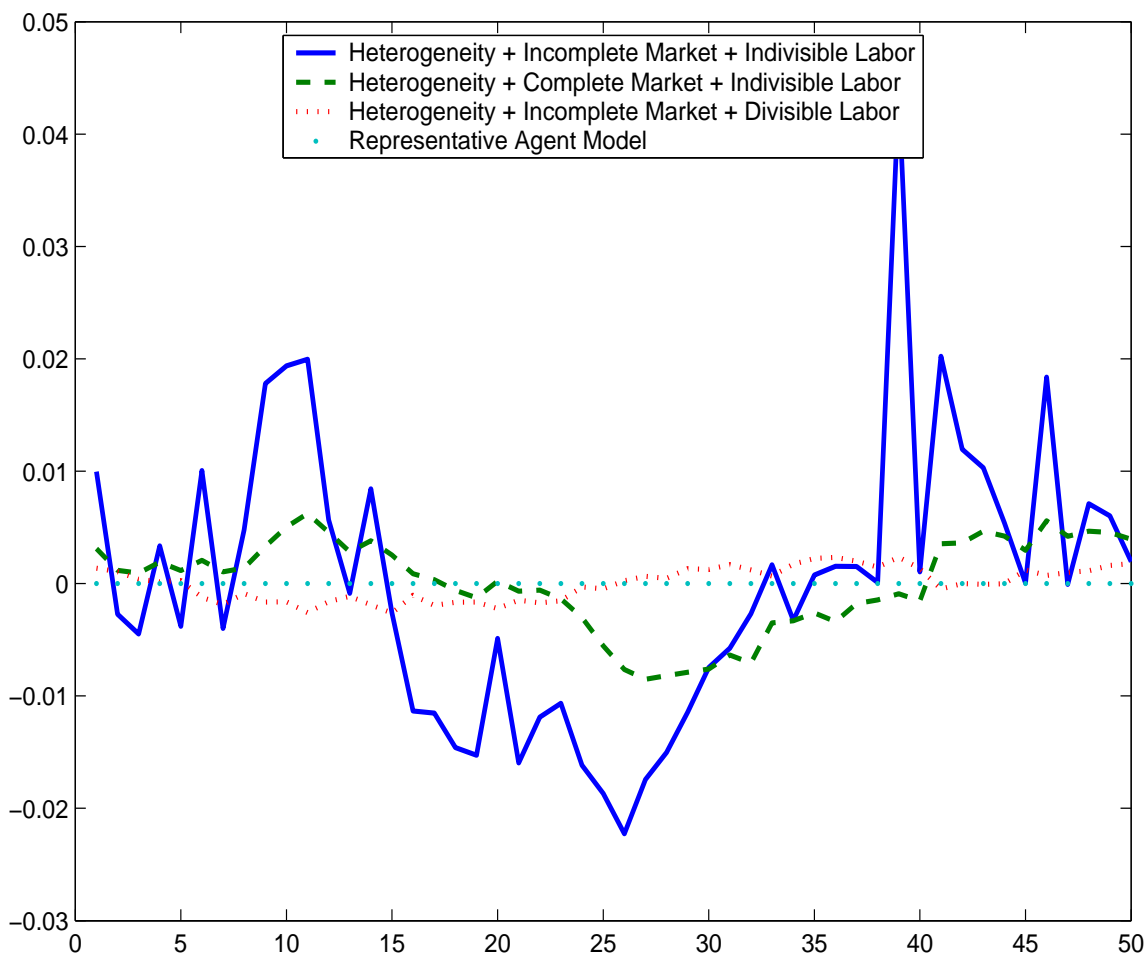
Note: The preference residual is computed from Equation (1) with the aggregate labor-supply elasticity (γ) of 1.

Figure 3: Total Hours and Preference Residual from the Benchmark Model



Note: The preference residual is computed from Equation (1) with the aggregate labor-supply elasticity (γ) of 1.

Figure 4: Preference Residuals from the Models



Note: The preference residual (B) is computed from Equation (1). We use the aggregate labor supply elasticity γ of 0.4 and 1, respectively, for divisible- and indivisible-labor models.

Figure 5: Total Hours Worked from the Models

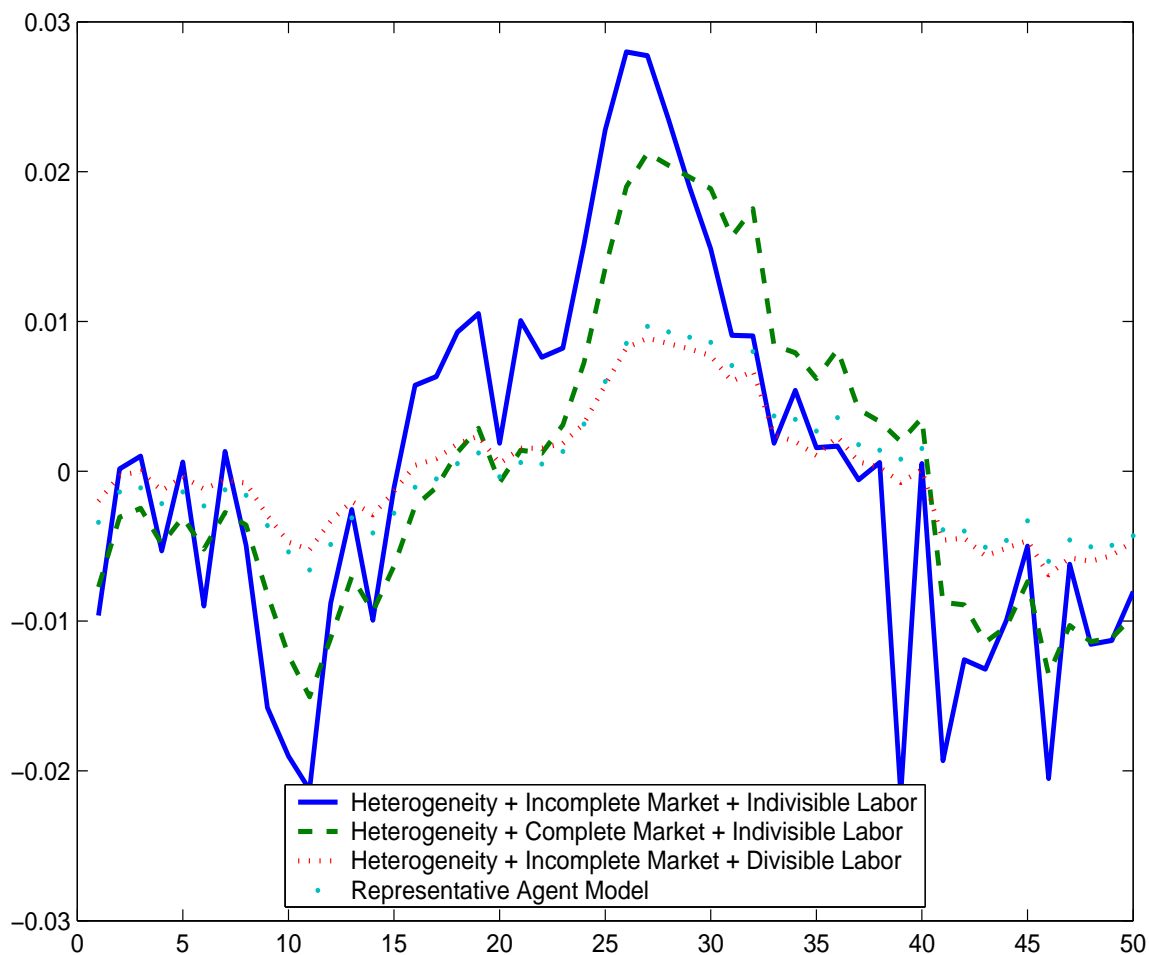


Figure 6: Effective Unit of Hours from the Models

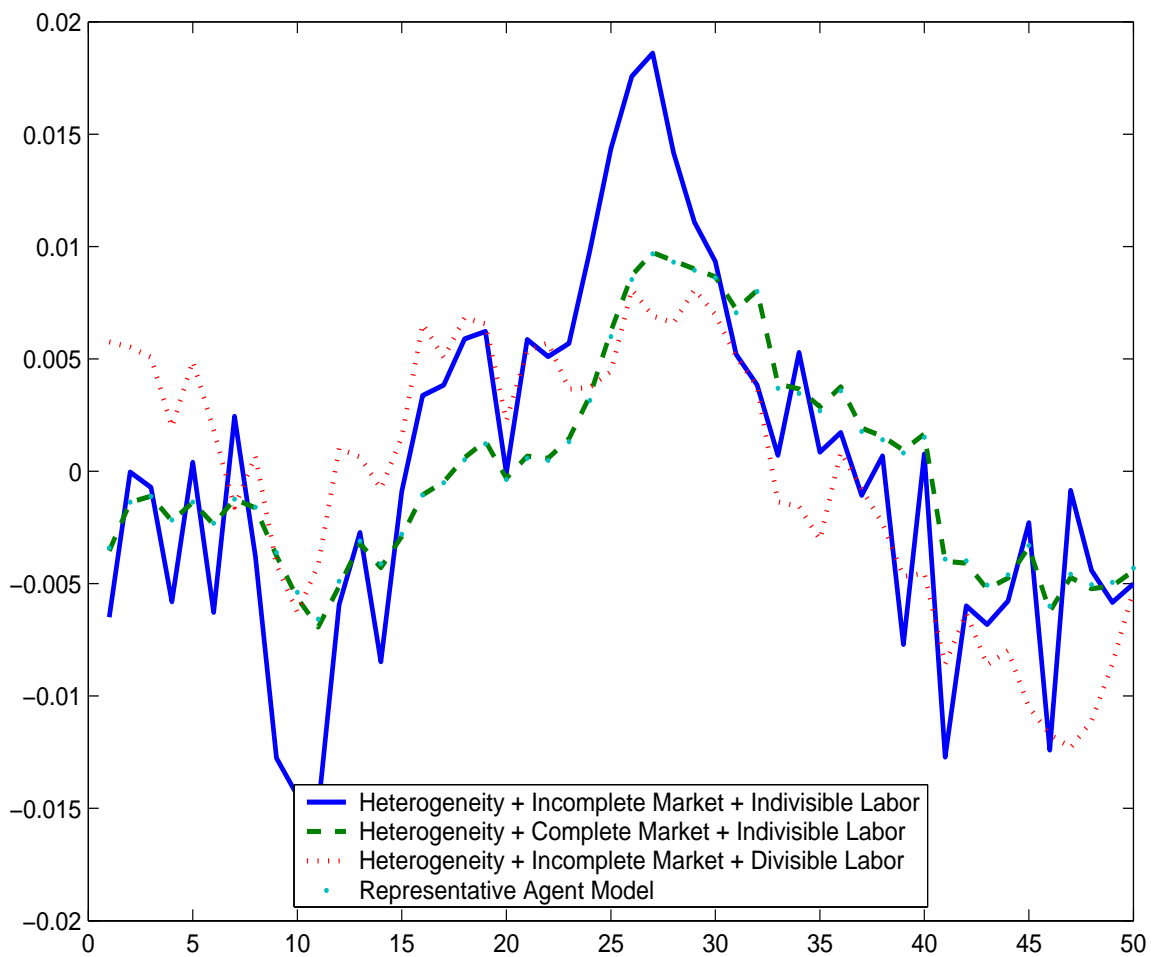


Figure 7: Aggregate Wages from the Models

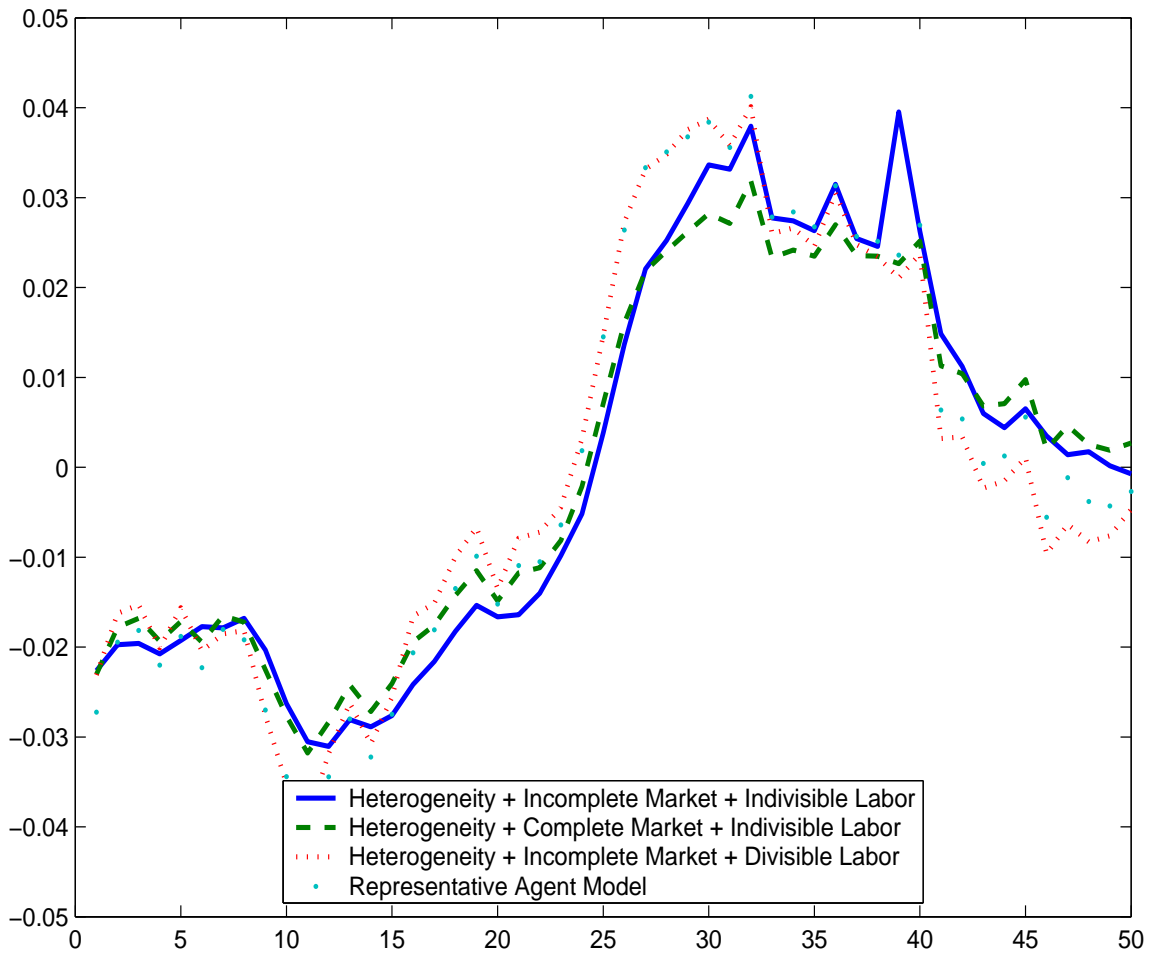


Figure 8: Aggregate Consumption from the Models

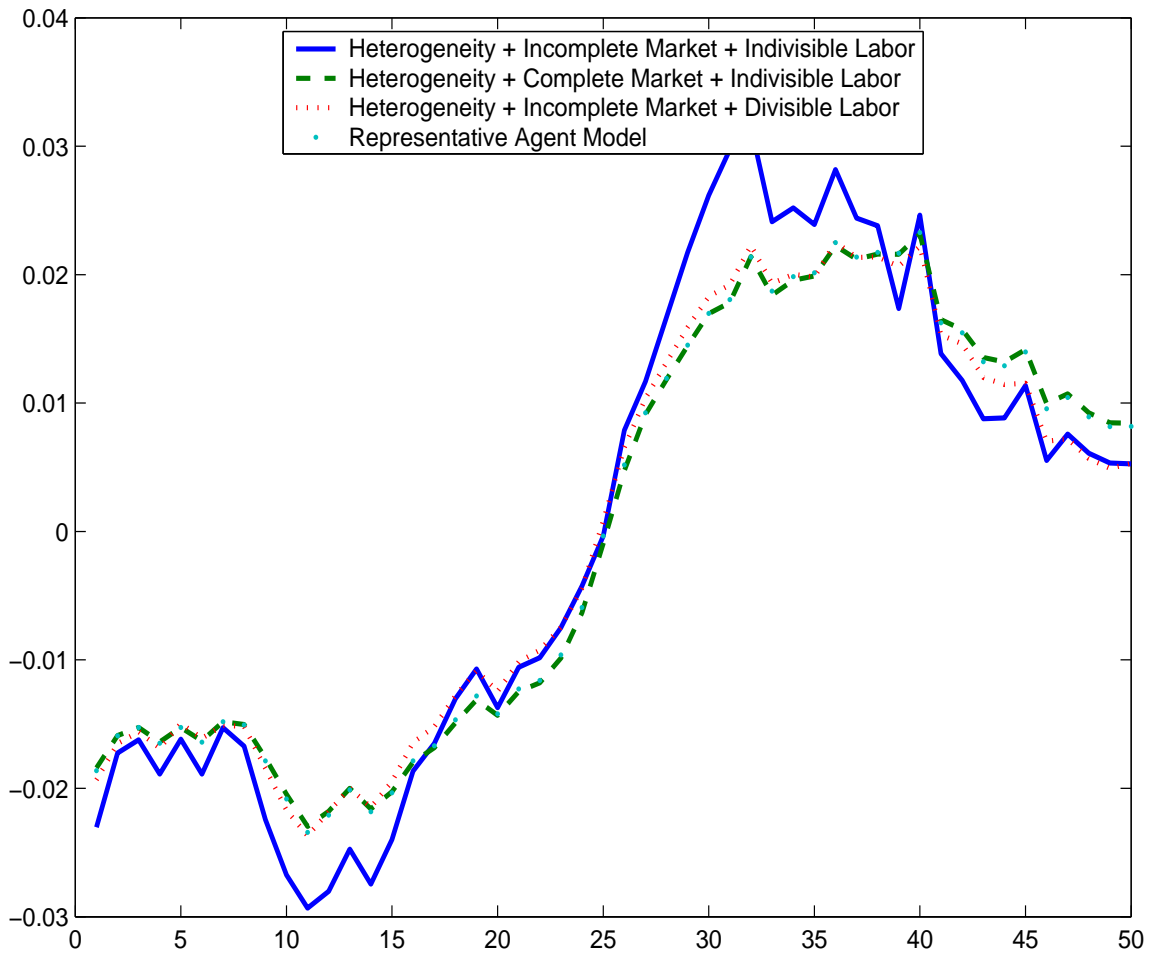


Figure 9: Asset Distribution of the Benchmark Model

