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by

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Abstract

Three essays on home production and the Chinese Economy

by

Yabin Wang

In this work I study several aspects of the Chinese economy using the notion of *home production*, that is the idea that households allocate time and financial resources to productive non-market activities.

In the first chapter, I study a new channel through which uncertainty hinders private consumption, namely a cautionary effect on household demand for capital goods. I develop a dynamic stochastic home production model with adjustment frictions on household capital, and characterize the optimal investment policy as a function of uncertainty, preferences and home production technology. A key prediction from the model is that higher uncertainty makes households more cautious in undertaking investments in home capital. I test the model prediction using a rich panel dataset on Chinese households, and document two types of cautionary effects: higher income uncertainty reduces the responsiveness of investments to increases in household disposable income and to a policy stimulus. I also find that household investment decisions are nearly insensitive to the variance of permanent income shocks and mainly respond to the variance of medium-run income shocks. These findings highlight the limits to policy interventions that subsidize household expenditures on appliances in conditions of uncertainty.

In "Durable Ownership and Time Allocation: Evidence from Chinas Home Appliances to the Countryside Rebate ", a joint paper with Ishani Tewari, I estimate the effect of labor saving household technologies on female labor force participation. To organize the empirical analysis, we formulate a model of home production which delivers testable predictions regarding the effect of durable price on adoption, and the impact of adoption on allocation of time between home and the market. Importantly, the model illustrates how changes in time use will be asymmetric for males and females in the household. In drawing the causal link between durable ownership and household time allocation, we exploit price shocks generated by the Home Appliances to the Countryside promotion, a durable goods rebate offered by the Chinese government to certain rural households for specific durables

like fridges and washing machines. Results show that eligible households had higher ownership propensity in these categories and this leads to a large and significant reduction in housework, as well as a sizable increase in market work time, and a boost in female LFP. Also consistent with the model, we find the reallocation of time is driven by females, rather than males, in the household.

In "Home Production and China's Hidden Consumption", I show that a significant part of China's private consumption is satisfied through unpaid home production. Using data from the American Time Use Survey and the China Health and Nutrition Survey between 2003 and 2010, I show that time spent at home work has been significantly higher in China than in the U.S., especially for women and retired individuals, although there are signs of a slow convergence towards the U.S. levels. Then I provide a structural analysis of Chinese household consumption and time use. I formulate a partial equilibrium home production model that improves on existing literature by modeling preferences over market vs. non-market work and by including non-employed household members. I show that this model is able to explain the key stylized facts about home production in China. Lastly, I find that the share of non-market consumption to measured GDP is around 40%.

I would like to thank Michael Hutchison, Carl Walsh, Joshua Aizenman and Grace Gu.

Chapter 1

Income Uncertainty and Investments in Household Capital: Evidence From China

A growing body of empirical and theoretical studies suggest that greater uncertainty is harmful for the macro-economy because it induces a so-called "cautionary effect", that is a wait-and-see attitude about incurring new expenditures (for example, see Bloom [2009] and Baker and Bloom [2013]). Most literature has focused either on firms' investment decisions or households' consumption decisions. This paper views households as both consumers and producers and studies the effect of income uncertainty on investments in capital goods used for home production. Understanding whether and how uncertainty affects household capital investments is particularly important for developing economies, where economic growth is often accompanied by an increase in uncertainty and where the home production sector is disproportionately large. I investigate these questions both empirically and theoretically.

Empirically, I use a rich panel dataset on Chinese households that includes detailed information on household appliances purchases, demographic information and income records. The Chinese economy provides an ideal environment for testing the effects of uncertainty on household investments in capital goods because the variance of household income has drastically increased in recent years (Chamon et al. [2013]) and is significantly larger than the income variance of U.S. households (Yu and Zhu [2013]). I document two types of cautionary effects on household appliances expenditure in the data. First, higher income uncertainty reduces the responsiveness of investments in appliances to increases in household disposable income. Second, higher income uncertainty reduces the responsiveness of household investments to a policy stimulus, namely a government-funded price rebate program on selected appliances. Motivated by these findings, I then develop a model of household capital investments and show that in the presence of adjustment frictions to capital stock, the model predicts the exact cautionary effects that are found in the data.

Turning to the theoretical investigation, I consider a dynamic infinite-horizon model, where a representative household obtains utility from a consumption bundle that contains both market-purchased goods and home-produced goods. The household allocates labor between the market sector and the home sector and controls the evolution of its financial assets and physical capital. I show that when the home production function has unitary elasticity of substitution between home work and home capital, it is possible to separate the original problem into two sub-problems, similarly to Bertola et al. [2005]. The first sub-problem is the household *intertemporal expenditure allocation* problem, which is characterized by a standard Euler equation in an appropriately defined expenditure variable. The second sub-problem is the household *capital adjustment* problem, which is the main interest of this paper. In the presence of adjustment frictions, it is optimal for the household to make an investment decision only when the current capital stock is far enough from an optimal target. The key prediction of the model is that higher uncertainty widens the adjustment boundaries, thus producing the observed cautionary effects.

Other predictions of the model are borne out in the data: for example, higher income volatility results in more frequent capital stock adjustments and households with more labor-intensive home production technologies adjust less frequently. I also report a finding that is not predicted by the current model although is not necessarily inconsistent with it. When I decompose income uncertainty into a permanent income shock variance and a transitory income shock variance, I find that household investment decisions are nearly insensitive to the former, while most of the reaction of investment to uncertainty can be attributed to its response to different levels of the transitory income shock variance. This suggests potential extensions to the model.

The finding that there are strong cautionary effects on household investment in capital goods contributes to a large and growing literature on the effects of uncertainty. A number of studies have studied the effects of uncertainty on firm's investments, see for example Bloom et al. [2007]. Many papers have explored the adjustment dynamics of expenditure on consumer durables using macro-data (Mankiw [1982], Bernanke [1985], Caballero and Engel [1993], Bertola and Caballero [1990], Bertola and Caballero [1994]) and micro-data (Bernanke [1984], Attanasio and Weber [1995], Bertola et al. [2005], Attanasio [2000], Zhu [2011]). However, the typical durables that have been studied are automobiles, housing and jewelry.

Studying the adjustment dynamics of durables within a home production framework is important for both theoretical and practical reasons. First, while it would be possible to use a reduced form approach, where appliances are treated as durables that enter the utility function (as in Bertola et al. [2005]), being explicit about their role in home production yields additional testable predictions. In my model, the optimal capital adjustment policy depends not only on the exogenous stochastic process and preferences, but also on the home production technology, which in turn affects the household allocation of time [1].

Moreover, understanding whether and how uncertainty affects household capital investments is particularly important for developing economies, where the home production sector is disproportionately large [2]. In this context, the finding that higher income uncertainty makes household investment in appliances less responsive has important policy implications. Appliances are often considered "engines of liberation" (Greenwood et al. [2005]): appliances adoption can potentially generate labor saving in home production, and spur an increase in market labor supply, especially for women. My findings highlight the limits to policy interventions that subsidize household expenditures on appliances in conditions of uncertainty.

Finally, this paper contributes to the literature on the effect of income uncertainty on the Chinese economy. Many commentators have noted that the Chinese economy has an excessively low share of private consumption relative to GDP. Several studies have tried to explain this fact with the increase in overall macroeconomic uncertainty associated with the transition to a market economy. Some of the empirical facts I document are consistent with the findings of the existing literature[3]. While most of the current studies have focused on

[1] Indeed the original Beckerian theory of the allocation of time (Becker [1965]) suggests some relation between the intensity with which the household engages in specific home activities and durables adjustment policies for any type of good (not just appliances).

[2] For example, using household level estimates of the home production function, in Wang [2013] I show that the share of non-market consumption to measured GDP is around 40% in China.

[3] For example, Chamon et al. [2013] finds that the remarkable increase in household saving rates in

a precautionary-savings channel (see for example, Chamon and Prasad [2010] and Chamon et al. [2013]), I provide an alternative mechanism for explaining how income uncertainty weakens private consumption – through the "cautionary effect" on household demand for durable goods.

The rest of the paper is as follows. Section 3.2 describes the data. Section 1.2 provides the measurement methodology and decomposition results on income uncertainty, outlines the empirical estimation procedure and presents several important empirical findings. Section 1.3 describes the theoretical framework through a representative household model, presents the qualitative predictions and provide insights to support the empirical estimation. Finally, section 3.6 concludes.

1.1 Data

For the empirical analysis, I use panel data from the *China Health and Nutrition Survey* (CHNS)[4]. The survey has a detailed document on household demographic characteristics, time use at individual level and household durable appliance purchases information at household level. Observations are across nine provinces that vary substantially in geography, economic development, and public resources. This survey was conducted in 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009 and 2011. The sample includes both urban and rural households. My baseline analysis involves a sample of households with household heads who are urban or rural residents, married, between age 25 to age 59, not students, and not retired.[5] I drop the small number of households reporting zero or missing household income, or with missing education or age information. I include households in all the waves in which they appear in the survey and satisfy all our requirements. Since there are some concerns regarding the quality of income information in the first wave of the survey, I also exclude 1989 from the sample. To limit the effects of extreme observations, I also drop

recent years is due to the increase in the variance of transitory shocks to income, rather than its permanent component.

[4]The survey is a collaborative effort between the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention. Details are at http://www.cpc.unc.edu/projects/china

[5]One reason to exclude retired individuals in the sample is that older individuals or retired individuals tend to have very different patterns in time allocation: spend significantly more time in home work than working individuals, possibly due to their low opportunity cost. Another reason is that retired individuals' household income are quite different from labor income, thus it would create biased estimation if we intend to investigate the variance of income.

some outliers on time use and individual annual income. Therefore, my final sample is an unbalanced panel consisting of 4056 households.[6]

Table 2.1 presents some descriptive statistics of the sample. It contains households whose head is between 25 and 59 years old. The median size of the household is two people. The majority of individuals (64%) are from rural areas. There is considerable heterogeneity in the level of education, income and working status in the population. The data provide detailed information on household durable goods. In particular, I look at the purchase and ownership of fridges, washing machines, microwave ovens and electrical cookers. There is substantial variability in these variables. To measure the overall household capital used for home production, I construct an index given by the sum of these four variables [7].

I study how individuals allocate their time by computing the number of hours per week that a person spends in different activities and classify them into three categories: market work, home work and leisure. Home production time is calculated as hours per week spent on taking care of children, cleaning the house, doing laundry, cooking, and doing grocery shopping. Market time is defined as hours per week spent on primary occupation. Leisure time is defined as the sum of hours spent per week on sedentary activity and physical activity.

1.2 Empirical Analysis

1.2.1 Measurement of Income Uncertainty

To implement an empirical test of the effect of income uncertainty, we need to first define the income variable and then find a measure of the income risk facing the household. The income measure in my analysis is household income, which includes labor income of the head, spouse, and other household members and does not include transfer income, capital income or subsidy. Household income is more relevant than individual income for making household consumption decisions, such as durable goods purchase decision.

I assume the family's total disposable income is comprised of three parts following Bernanke [1985]: (1) the deterministic component, which is the pattern of lifetime income that can be projected from the basic demographic characteristics of the family, (2)

[6]The sample is unbalanced also because of new respondents introduced into the survey, old respondents moved out of the survey, and transitions of household members into retirement or aging.

[7]The choice for the four appliances are based on the consideration of their usage in home production.

the lifetime prospects component (permanent component), which is stochastic, depends on the household current evaluation of its members' skills and long run opportunities. Any change in this component is considered unanticipated, (3) the windfall component (transitory component), which is also stochastic and is meant to capture purely transitory changes in income.

The first step is to remove the predictable component of income growth, namely part (1). I run Mincerian income regression of log income on age, education, occupation, and household demographic variables.

$$I_{i,t} = \beta X_{i,t} + y_{i,t}$$

where $I_{i,t}$ is the log of household income for household i at time t. $X_{i,t}$ includes a set of demographic variables, in which I include age, education, occupation, marriage status, household size, dummy for urban, number of earners, and working dummy. The regression is run separately for each wave. I then detrend the predicted values for economy-wide growth in income. I obtain a time series of residual income $\{y_{i,t}\}_{t=1991}^{2011}$ for each household i. This normalized residual income series therefore should show no trend over the sample period. Moreover, this residual series is essentially the part of household income that cannot be explained by the household characteristics included in the above income regression. Thus, we mainly focus on the series of residuals $\{y_{i,t}\}$ to infer the degree of income uncertainty for a particular household i.

I then decompose the residual income into permanent income component (namely part (2)) and transitory income component (namely part (3))[8].

$$y_t = p_t + \epsilon_t$$

The permanent component p_t follows a random walk with a drift:

$$p_t = p_{t-1} + \eta_t$$

where η_t is the shock to p_t in period t. As standard in the literature, I assume that the permanent shock η and the transitory shock ϵ to income are white noise and uncorrelated with each other at all lags and leads, i.e. they are *i.i.d.* across households and time. Finally,

[8]Household index i is omitted when there is no confusion.

I use the following notation for the variance of income shocks:

$$var(\eta_t) = \sigma_\eta^2$$
$$var(\epsilon_t) = \sigma_\epsilon^2$$

Evidence has shown that income shocks do have a very persistent, near-random walk component[9]. The basic approach I use to estimate σ_η^2 and σ_ϵ^2 is the same as that developed in Carroll and Samwick [1997]'s seminal study, to which the reader is referred for additional motivation and clarification[10].

Table 1.2 presents the estimated variance of permanent and transitory shocks to household income. From a pooling regression on all the households included in the sample, I find the variances of innovations to permanent component and transitory component to be very different in size: around 0.019 for permanent shock and 0.371 for transitory shock. I also report empirical estimates of income uncertainty by occupation, work unit type, education, and age. Inspection of the grouped results reveals considerable heterogeneity across families belong to different categories. When the household head works in the government sector or in state-owned enterprises, the family faces low income uncertainty in both types of income shocks. Income uncertainty is particularly high for families where the household head works as a service worker, farmer or manager. Moreover, household with less educated members face higher uncertainty.

1.2.2 Income Uncertainty and Household Capital Ownership

I then study how income uncertainty and other key household characteristics correlate with different levels of durable ownership. Table 1.3 shows that households with above-average household capital earn more income and spend more time in doing home production. There seem to be only minor differences in the variance of the permanent component of income shocks across families with different levels of durable ownership. However, households with below-average capital face significantly higher uncertainty in transitory income shocks[11].

[9] See MaCurdy(1982), Abowd and Card(1989). Guvenen [2009] and Guvenen [2007] provide detailed review of literature on measuring the income uncertainty.

[10] The technical details on estimation are omitted in the paper and available upon request

[11] I will examine the correlation between household durable ownership and income uncertainty under different levels of home production in a more detailed regression analysis later.

Motivated by this summary evidence, I run a number of regressions to examine how income volatility is related to the level of durable ownership. I study this correlation using the following specification:

$$Pr(\text{Own}_{it} = 1) = \gamma_1 \sigma^2_{\eta_i} + \gamma_2 \sigma^2_{\epsilon_i} + \gamma_3 \text{urban} + X_{it}\gamma_4 + A_t + P_i + \upsilon_{1it} \tag{1.1}$$

X_{it} is a vector of the control covariates, including age, education of household head, marriage status, household income, and household size. A_t and P_i are year fixed effects and province fixed effects respectively. Table 1.5 shows that households that face higher transitory shock variance are less likely to own appliances. The results are consistent and significant across different types of durables. Households residing in urban areas, with higher income and whose head is married are more likely to own household electrical appliances.

1.2.3 Income Uncertainty and the Value of Household Capital

Using ownership dummies we can only measure household capital in terms of the number of different appliances. In reality households also choose to hold more or less expensive types of capital. To look at this dimension, I obtain the self-reported monetary value of each appliance the household owns. I then run the following OLS regression:

$$\text{Durable value}_{it} = \beta_1 \sigma^2_{\eta_i} + \beta_2 \sigma^2_{\epsilon_i} + \beta_3 \text{urban} + X_{it}\beta_4 + A_t + P_i + \upsilon_{2it} \tag{1.2}$$

Results from Table 1.4 show that if an household faces more uncertain transitory income shocks, it tends to purchase less expensive household durables. As expected, household with a higher household income level, tends to own more expensive appliances.

1.2.4 Investment Frequency

In this section, we turn to look at how different components of household income uncertainty affect the decision to invest in household capital. I test this question using an investment probit regression controlling for time and province fixed effects as well as other time-varying covariates. The specification is as follows:

$$Pr(\text{Invest}_{it} = 1) = \alpha_1 \sigma^2_{\eta_i} + \alpha_2 \sigma^2_{\epsilon_i} + \alpha_3 \text{stock} + \alpha_4 \text{urban} + X_{it}\alpha_5 + A_t + P_i + \upsilon_{3it} \tag{1.3}$$

where α_1 and α_2 are parameters that measure the response of the probability of making investments to permanent income shock variance ($\sigma^2_{\eta_i}$) and transitory income shock variance ($\sigma^2_{\epsilon_i}$) respectively. "stock" represents the current durable stock level of household i. The focus in on the sign of α_1, α_2 and α_3. The regression is run separately for each of the four household durables: washing machine, fridge, microwave oven, and electrical cooker. Results from Table 1.6 show that household durable investment decisions are very responsive to the variance of transitory income shocks as opposed to permanent income shocks across different durable goods. In particular, I find that households with a higher transitory income shock variance are more likely to make adjustments to household durables within the current period. That means that within a given a period of time, the frequency of adjustment is higher for families with higher income volatility. As expected, households with a higher current durable stock are less likely to make investments.

1.2.5 Investment Responsiveness to Shocks

The evidence I have presented so far suggests that households with higher income uncertainty hold a smaller home capital stock and adjust it more frequently relatively to lower uncertainty households. For policy purposes, a more interesting question is how the *responsiveness* of durable investments to shocks differs (if at all) between households with higher income uncertainty and households with lower income uncertainty. I implement this test using two types of shocks: (1) income shocks, i.e. changes in household disposable income and (2) a policy stimulus, i.e. a reduction in appliance prices implemented by a government funded price rebate program. In these tests I focus on uncertainty in temporary income shocks, as the previous regressions have consistently shown no significant effects of uncertainty in permanent income shocks. To obtain clear evidence on the qualitative effect of uncertainty, I consider only households with high vs. low income variance. In particular, I compare households whose income variance belongs to the lower quartile of the variance distribution to households whose variance belongs to the upper quartile. Thus I define a high-uncertainty dummy as:

$$H_{\sigma^2_{\epsilon_i}} = \begin{cases} 1 & \text{if } \sigma^2_{\epsilon_i} > \text{top 25th percentile} \\ 0 & \text{if } \sigma^2_{\epsilon_i} < \text{bottom 25th percentile} \end{cases} \tag{1.4}$$

The results obtained from regression (1.3) suggest that the investment probability is positively related to the high-uncertainty dummy.

Income Shock

First, I study the effect of income shocks. For each period and household, I compute the change in household real disposable income from period $t-1$ to period t, denoted ΔI_{it}. To test how uncertainty affects investment responsiveness to income shocks I add to the investment probit regression an interaction term between ΔI_{it} and the high-uncertainty dummy $H_{\sigma^2_{\epsilon_i}}$. Thus I run the following regression:

$$Pr(\text{Invest}_{it} = 1) = \lambda_1 H_{\sigma^2_{\epsilon_i}} + \lambda_2 \Delta I_{it} + \lambda_3 H_{\sigma^2_{\epsilon_i}} \Delta I_{it} + \lambda_4 \text{stock} + \lambda_5 \text{urban} + A_t + P_i + \upsilon_{4it} \tag{1.5}$$

The key parameter is the interaction term coefficient, λ_3. I present the results in Table 1.7. The coefficient estimate for λ_1 is positive, meaning that households with higher income volatility are more likely to invest in any given period, which coincides with the previous finding. As expected, λ_2 is positive, indicating that an increase in income makes the household more likely to invest. The probability of investing is also negatively correlated to current durable stock ($\lambda_4 < 0$). Most important, I find a significant negative estimate for λ_3 (-0.013), which implies that given the same income increase, households with higher income uncertainty tend to be more cautious in making investment. This reflects a wait-and-see attitude induced by high uncertainty.

Price Cut

I then estimate the cautionary effect of uncertainty on household investment using a different shock, namely a reduction in appliance prices implemented by a government funded price rebate program[12]. Assuming that appliances are normal goods, we would expect an increase of durable investment to follow the rebate program. However, the evidence accumulated so far suggests that high income uncertainty can hinder the potential policy-induced boost in household investment. To test this hypothesis, I run an investment

[12] "Home Appliances Going to the Countryside" (HAGC) rebate is a five-year, government-sponsored promotion aimed at stimulating consumption of home appliances in rural China. Households were entitled to rebates of thirteen percent when they bought certain categories of durable goods.

probit regression on two separate samples, one with households in the top 25 percentile of the uncertainty distribution and one with households in the bottom 25 percentile:

$$Pr(\text{Invest}_{it} = 1) = \delta_1 \text{Price rebate} + \delta_2 \text{stock} + A_t + P_i + \upsilon_{5it} \tag{1.6}$$

where price rebate is a dummy variable equal to 1 if household resides in the eligible area. Table 1.8 presents the findings.

For both sub-samples, δ_1 is positive, indicating that the rebate program succeeded in boosting appliances adoption for at least some of the households in the eligible areas. However, comparing the coefficients between the two samples, it is possible to infer that the responsiveness of durable investments to the price cut is halved for household with high uncertainty relative to low uncertainty households. Uncertainty therefore limits the potential effect of a policy stimulus on household capital investments.

1.3 Theory

This section provides a theoretical analysis of household capital investments under uncertainty. I consider a household dynamic optimization model that incorporates home production, investment adjustment frictions and uncertainty. First I set up the frictionless problem and illustrate how to separate it into two tractable sub-problems. Then I add adjustment frictions and obtain predictions that provide support for the empirical evidence discussed above.

1.3.1 A Household Investment Problem with Home Production

Assume there is an infinitely-lived household maximizing its expected discounted lifetime utility from consumption:

$$E_t \sum_{t=0}^{\infty} \beta^t \ln c_t \tag{1.7}$$

The household total consumption c_t is obtained from two sources: purchased from the market c_{mt} and produced at home c_{ht}[13]. Assume total consumption c_t is a Cobb-Douglas

[13]Clearly, here I focus on a case where home-produced good and market-purchase good are not perfect substitutes.

composite of c_{mt} and c_{ht}.

$$c_t = c_{mt}^{\alpha} c_{ht}^{1-\alpha} \quad \alpha \in (0,1) \tag{1.8}$$

The household faces the following budget constraint:

$$c_{mt} + s_{t+1} + px_t = w_t m_t + (1+r)s_t \tag{1.9}$$

where: c_{mt} is consumption of market-produced goods (assumed to be the numeraire), s_t is the stock of financial savings, x_t is durable investment and m_t is the number of hours the household allocates to work in the market. The household takes durable price p, interest rate r and wage w_t as given. The problem's budget constraint features a stochastic process of wage w_t[14].

The household allocates labor between the market and the home sector. Denoting by h_t the number of hours the household allocates to work at home and by T the total time endowment, the time constraint can be written as:

$$m_t + h_t = T \tag{1.10}$$

Home production hours and capital inputs are embedded in a Cobb-Douglas technology[15].

$$c_{ht} = h_t^{\gamma} k_t^{1-\gamma} \quad \gamma \in (0,1) \tag{1.11}$$

Household capital evolves according to the standard law of motion:

$$k_{t+1} = (1-\delta)k_t + x_t \tag{1.12}$$

where δ is the depreciation rate. Summing up, the household problem is:

$$\max E_t \sum_{t=0}^{\infty} \beta^t \ln c_t \tag{1.13}$$

subject to (1.8), (1.9), (1.10), (1.11), (1.12)

[14] I will specify the exogenous stochastic process later after a great simplification of the original model.

[15] Cobb-Douglas specification is a standard modeling choice in the literature as in most of the models surveyed by Aguiar et al. [2012]. Moreover, the assumption on Cobb-Douglas production functional form is very useful for a future simplification of the model.

1.3.2 Separation of Intertemporal and Adjustment Dynamics

Intuitively, the household has to deal with two, possibly intertwined, issues: 1) how to allocate resources to smooth consumption over time and 2) how to allocate resources between the market and home sectors. Here I show that under certain conditions it is possible to separate these two aspects of the household decision problem. The simplification technique applied here is in the spirit of Bertola et al. [2005][16].

First, I show that it is possible to rewrite the budget constraint in terms of variables that describe the total amount of wealth and expenditure without the need of keeping track of the market-home allocation problem. Define a as the monetary value of total assets, including both financial assets, namely savings, and physical assets, evaluated at their market price:

$$a \equiv s + pk \tag{1.14}$$

Next, I define an index of total expenditure that includes both market and home expenditures. In order to include also the expenditure on capital services, it is necessary to look at the user cost of household capital, v. As in investment theory, the user cost of capital is defined as the economic cost incurred by consumers to *use* the capital for a given period of time. Here I consider user costs that arise from depreciation of the capital value and from forsaking alternative investment opportunities of one's funds[17]. Formally the user cost of capital is defined as:

$$v \equiv p(r + \delta) \tag{1.15}$$

Then I define q as the total expenditure spent on purchasing (1) market non-durable consumption, (2) household capital services (notionally rented at the user cost v) and (3) home production hours (notionally bought out of the total time endowment at price equal to the

[16] Bertola et al. [2005] study a model where the household derives utility from a non-durable consumption good and a durable consumption good. In my model the durable good does not enter the utility function directly. In this case the analysis is potentially complicated by the fact that wage changes do not have only an income effect on the durable expenditure, but also a substitution effect, as the household substitutes capital for home work. There are also other ways of solving models that combine consumption smoothing and some form of adjustment problem: see Attanasio [2000] and Padula [2000] for references and discussion.

[17] User costs that arise from the dynamics of the purchase and resale price of durable goods, which generate capital gains or losses are excluded from v.

wage rate w):

$$q \equiv c_m + vk + wh \tag{1.16}$$

Using definitions (1.14), (1.15), (1.16) together with the the capital law of motion (1.12) and the household time constraint (1.10), it is now possible to rewrite the budget constraint (1.9) as follows:

$$q_t + a_{t+1} = w_t T + (1+r)a_t \tag{1.17}$$

The new budget constraint implies that :

$$\begin{aligned} \text{Total expenditure} + \text{Next period assets} &= \text{Total resources} = \\ &= \text{Money value of time endowment} + \text{Return on assets} \end{aligned}$$

Note that this budget constraint does not contain any reference to the market-home allocation problem. Household preferences, however, are defined over a bundle of home consumption and market consumption. Next, I show that it is also possible to rewrite the household period utility as the sum of two separate terms, depending on total expenditure q and home capital respectively.

Consider the household intra-temporal problem of allocating resources between market and home (in the absence of adjustment frictions to the capital stock). By choosing home work hours h and home capital k at time t and taking the total expenditure q as given, the household problem can be written as [18]:

$$\max_{h,k} \; c_m^{\alpha} c_h^{1-\alpha} \tag{1.18}$$

$$\begin{aligned} \text{subject to} \quad & c_m + vk + wh = q \\ & c_h = h^{\gamma} k^{1-\gamma} \end{aligned}$$

The solution involves allocating a constant share of total expenditure q to market consumption c_m, durables consumption vk, and home production time wh. Denoting by y^* the optimal frictionless value of choice variable y, it is possible to show that the solution is the

[18] Time subscript t is omitted whenever there is no confusion.

following:

$$c_m^* = \alpha q \tag{1.19}$$

$$k^* = \frac{q}{v}(1-\alpha)(1-\gamma) \tag{1.20}$$

$$h^* = \frac{q}{w}(1-\alpha)\gamma \tag{1.21}$$

Equation (1.20) and (1.21) give the optimal choices of home durables and home hours when there is no friction on adjusting durables investment. Note that this solution has the typical Cobb-Douglas properties: homogenous of degree 0 in q, w, v and no cross-price effect (i.e. $\frac{\partial k^*}{\partial w} = 0$).

Next I solve the household intra-temporal problem for h while treating k as given. This is useful for constructing the value function of the optimization problem when there are frictions on durable adjustment. After obtaining the solution for h with fixed k, we are able to derive the total consumption c as a function of total expenditure q and the ratio of household durables stock level k to the optimal stock level k^* in a given time period. The period utility of the household can be written as:

$$\ln c_t = \ln q_t + g(z_t)$$

where z_t is the logarithm of the ratio of household capital k_t to the optimal stock level k^*:

$$z_t \equiv \ln \frac{k_t}{k_t^*} \tag{1.22}$$

The function $g(\cdot)$ is given by

$$g(z_t) \equiv (1-\theta)\ln(\frac{1}{\theta} - e^{z_t}) + \theta z_t \tag{1.23}$$

and the parameter θ is defined as:

$$\theta \equiv (1-\alpha)(1-\gamma)$$

The function $g(z)$ describes the utility from tracking the intratemporal optimal level of household capital and it is plotted in Figure 1.1. It is a single-peaked function and its global maximum is achieved at $z = 0$, that is when $k = k^*$.

We are now ready to rewrite the original household problem (1.13) as:

$$\max_{\{q_t, z_t\}} \; E_t \sum_{t=0}^{\infty} \beta^t \Big[\ln q_t + g(z_t) \Big] \tag{1.24}$$
$$\text{s.t.} \quad q_t + a_{t+1} = w_t T + (1+r) a_t$$

Note that since utility obtained from total expenditure q_t and utility obtained from the intra-temporal allocation of durables $g(z_t)$ are additively separable and z_t does not appear in the budget constraint, the household problem can be broken down into two sub-problems. The first one deals with the inter-temporal allocation of expenditures subject to household's budget constraint:

$$\max_{q_t} \; E_t \sum_{t=0}^{\infty} \beta^t \ln q_t \tag{1.25}$$
$$\text{s.t.} \quad q_t + a_{t+1} = w_t T + (1+r) a_t$$

and leads to the standard Euler equation:

$$\frac{1}{q_t} = E_t \frac{1}{q_{t+1}} \beta (1+r)$$

1.3.3 Optimal Investment Decision with Adjustment Friction

The second sub-problem deals with tracking the intratemporal optimal level of household capital, namely, the household *capital adjustment* problem.

$$\max_{\{z_t\}} \; E_t \sum_{t=0}^{\infty} \beta^t g(z_t) \tag{1.26}$$

Without any adjustment friction of household capital, the optimal policy chosen by the household is to maximize $g(z_t)$ at every instant by setting its current durable level equal to the optimal target level, i.e. $k_t = k_t^*$, and $z_t = 0$. In other words, the household would make instantaneous adjustments to the capital stock in each period whenever it deviates from the optimal target. However, the durable goods market is not frictionless. Costs of adjusting durable stocks may arise from the structure of second-hand market, or from dislike of shopping, or from replacement cost such as searching cost. Thus I introduce an adjustment friction. I assume that every time the capital stock is adjusted the household incurs a fixed utility cost $\phi > 0$. In the literature, adjustment costs are modeled either as affecting utility or as elements of budget constraint. In this paper, I use the first strategy as a matter of analytical convenience: under adjustment frictions separation of problem (1.24) into (1.25) and (1.26) is allowed only if the friction does not affect the budget constraint.

I reformulate the capital adjustment problem in a recursive way. The value function of a household that chooses not to adjust its capital stock in a given period is:

$$V^n(z) = g(z) + \beta EV\left(z'|z\right) \tag{1.27}$$

By incurring the utility cost ϕ and choosing the new capital stock log-ratio $\tilde{z}$, the value function of a household that adjusts its household durables in a given period is:

$$V^a = -\phi + \max_{\tilde{z}} \left\{g(\tilde{z}) + \beta EV(z'|\tilde{z})\right\} \tag{1.28}$$

The optimization problem of a household is to decide whether or not to adjust the current household capital stock in each period. The value function of a household in a given period is therefore the maximum between adjusting and not adjusting, given the current state z:

$$V(z) = \max\left\{V^a, V^n(z)\right\} \tag{1.29}$$

In the presence of adjustment frictions, it is optimal for the household to make an investment decision only when the current capital stock is sufficiently far from the optimal target. Thus household investments are lumpy and infrequent, and inaction is optimal most of the time. In particular there are two adjustment thresholds, values of z that satisfy the following condition:

$$g(z) + \beta EV\left(z'|z\right) = V^a \tag{1.30}$$

When the log-ratio of actual capital to optimal frictionless capital reaches one of these two thresholds, the household adjusts the capital stock to an optimal return point, z^*, that satisfies:

$$z^* \equiv \max_{\tilde{z}} \left\{g(\tilde{z}) + \beta EV(z'|\tilde{z})\right\} \tag{1.31}$$

The optimal return point, z^*, is not necessarily equal to 0, although it is likely to be close to it.

1.3.4 Model Solution and Predictions

In this section, I present qualitative predictions from model simulation and provide insights to support the empirical estimation. In order to solve the model it is necessary to specify the stochastic process for the state variable z. There are two exogenous sources of dynamics in the state variable z. In each period the current capital stock depreciates and the optimal frictionless capital stock, k^* , changes randomly over time as the economic environment changes. Assuming that the user cost of capital is constant, the expression of k^* given in equation (1.20) implies that fluctuations in the optimal frictionless capital stock are determined by changes in the current expenditure q. In turn, the evolution of expenditure is affected by exogenous changes in the wage rate w. Ideally, it should be possible to derive the dynamics of k^* from those of w, by solving the intertemporal expenditure allocation problem, (1.25), first. However, as noted by Bertola et al. [2005] "analytic expressions are only available for restrictive utility specifications, and numerical solution is practical only for simple specifications of the consumer's environment". Thus I follow Bertola et al. [2005] and specify an exogenous stochastic process for the expenditure, noting that uncertainty in the expenditure process would still reflect the variability of uninsurable income shocks. Thus I assume total expenditure $\{q_t\}$ follows random walk with drift:

$$\ln q' = \mu + \ln q + \varepsilon \tag{1.32}$$

Here ε is a normally distributed random variable, with mean 0 and variance σ_ε^2 . The parameter $\mu \geq 0$ capture the predicted growth in expenditure.

During time periods over which there is no capital adjustment ($x = 0$), the law of motion of capital, equation (1.12), implies:

$$\ln k' = \ln k + \ln(1-\delta) \simeq \ln k - \frac{\delta}{1-\delta} \tag{1.33}$$

when δ is close to zero. Equation (1.33) describes the dynamics of household capital: actual capital depreciates linearly each period. Given the relationship between log-ratio of capital z and household capital k defined by equation (1.22), it is then possible to show that the log-ratio of actual capital to optimal frictionless capital follows the process:

$$z' = -\mu - \frac{\delta}{1-\delta} + z + \varepsilon \tag{1.34}$$

Note that the process of z described by equation (1.34) holds only within the zones of no capital adjustment. The z variable, log-ratio of actual capital to optimal capital tends to decrease over time with a negative trend $-\mu - \frac{\delta}{1-\delta}$. One reason is that expenditure and therefore optimal capital may tend to increase over time while actual capital depreciates linearly each period. Qualitatively, the volatility σ_ε^2 reflects the uncertainty of household income.

I solve the model numerically by value function iteration on a discretized state-space. The parameter values chosen in the computation are presented in Table 1.9. To illustrate the pattern of adjustment dynamics of the capital log-ratio, z_t, I plot the results from a simulation in Figure 1.2. Note that when an adjustment is triggered, the household adjusts to a value $z^* > 0$, since the negative drift will cause z to fall over time. In order to illustrate the adjustment dynamics of household capital more clearly, I look at the simulated behavior of the household in terms of the log of the capital stock. Figure 1.3 plots the the simulated series of $\ln k_t$ and $\ln k_t^*$, together with the optimal adjustment threshold in the log-k-space (with starting values $\ln k_0 = \ln k_0^* = 0$). Adjustments are infrequent. During periods of no investment the household capital stock falls because of depreciation. When household capital reaches the adjustment threshold and an adjustment is triggered, the household invests to bring its capital stock back to a value k close to the optimal frictionless capital level k^*. More specifically, it is optimal for the household to pick a value $k > k^*$ to account for the negative drift.

I then investigate the relationship between volatility σ_ε^2 and the frequency of optimal adjustments. I solve the model for different values of σ_ε^2, I simulated 100000 periods for each model and compute the endogenous frequency of investments. Figure 1.4 plots the results, showing that σ_ε^2 and the adjustment frequency are mostly positively related. This is consistent with the evidence that Chinese households with higher income volatility show a higher frequency of investments.

The model also gives additional testable predictions about the relation beween household investments and the home production technology . I solve the model separately with a high γ (more labor intensive technology) and a low γ (more capital intensive technology). I then run the same simulation procedures as above, and compute the endogenous frequency of investments with these two different home production technologies. As shown by Figure 1.4, households that have a more labor intensive home production technology tend to make less frequent adjustments to household capital.

Finally, I illustrate that the model is consistent with the observed cautionary effects of uncertainty. A key comparative statics of this model, that is typical for the class of stochastic control models with fixed costs, is that higher volatility induces a wider inaction region. In order to illustrate this result, I solve the model for different values of σ_ε^2. Figure 1.5 plots the optimal adjustment thresholds in the log-ratio space as well as the optimal return point, z^*, as a function of σ_ε^2. As income uncertainty rises, the upper bound increases while the lower bound falls, resulting in a widening "inaction" band for household capital adjustment. This framework provides an explanation for the fact that households facing more uncertainty are less responsive to shocks. Income shocks and appliance price changes affect the optimal frictionless capital stock that is determined by the following expression, repeated for convenience:

$$k^* = \frac{q}{v}(1-\alpha)(1-\gamma)$$

A positive income shock rises k^* by increasing q, the current level of expenditure, while a price cut is equivalent to a reduction in v. Since households with more uncertainty adopt a wider inaction band, a given shock to the household target capital stock is less likely to trigger an investment when the household faces higher uncertainty. This is illustrated in Figures 1.6 and 1.7. The time of the shock is marked by a dashed vertical line. Under low uncertainty, Figure 1.6, the shock to k^* immediately triggers an investment. When uncertainty is higher, as in the simulation plotted in Figure 1.7, the inaction band is wider. In the example, the shock does not induce any investment and only at a later date is household capital adjusted.

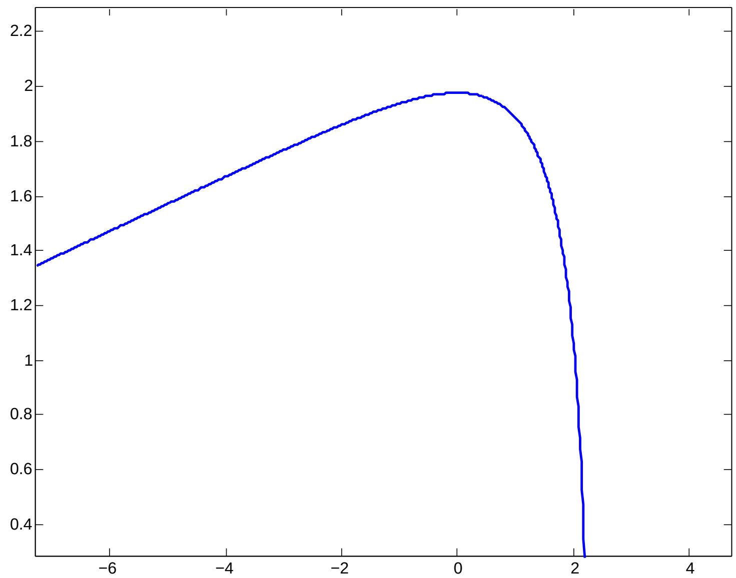
1.4 Conclusions

A growing body of empirical and theoretical studies suggest that greater uncertainty is harmful for the macro-economy because it induces a so-called "cautionary effect", that is a wait-and-see attitude about incurring new expenditures (for example, see Bloom [2009] and Baker and Bloom [2013]). Most literature has focused either on firms' investment decisions or households' consumption decisions. This paper views households as both consumers and producers and studies the effect of income uncertainty on investments in capital goods used for home production. Understanding whether and how uncertainty affects household capital investments is particularly important for developing economies, where economic growth is often accompanied by an increase in uncertainty and where the home production sector is disproportionately large. I investigate these questions both empirically and theoretically.

I develop a dynamic stochastic home production model with adjustment frictions on household capital investment, and characterize the optimal investment policy as a function of uncertainty, preferences and home production technology. A key prediction from the model is that higher uncertainty makes households more cautious in undertaking investment in home capital. I test the model prediction using a rich panel dataset on Chinese households, and document two types of "cautionary effects": higher income uncertainty reduces the responsiveness of investments to increases in household disposable income and to policy stimulus. I also find that household investment decisions are nearly insensitive to the variance of permanent income shocks and mainly respond to the variance of transitory income shocks.

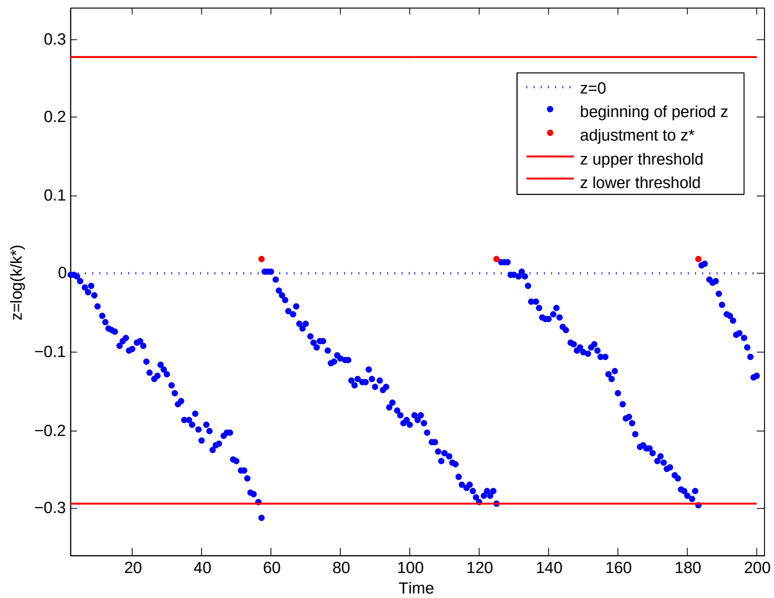
1.5 Figures and Tables

Figure 1.1: The Function g(z)



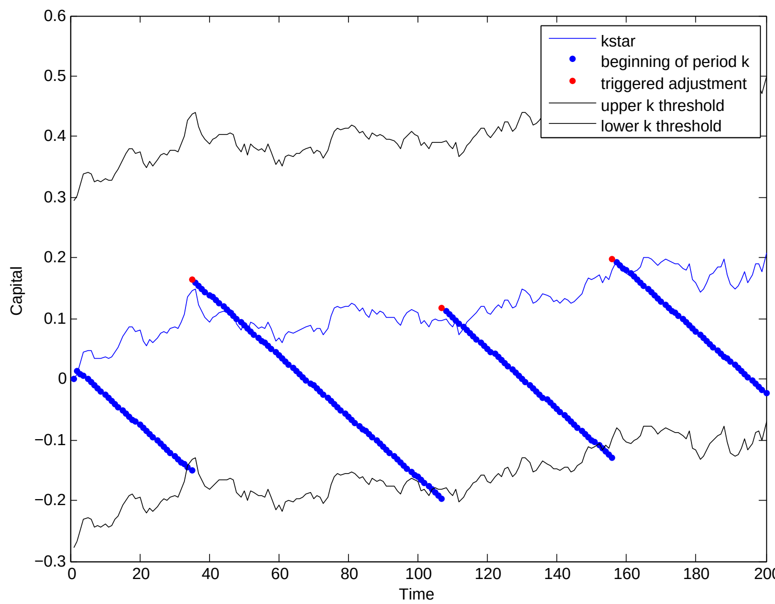
Notes: Figure 1.1 illustrates the shape of the function $g(z)$, representing the utility from tracking the optimal frictionless capital stock. In this figure $\theta = 0.1$.

Figure 1.2: The Dynamics of z – Capital Ratio Adjustments



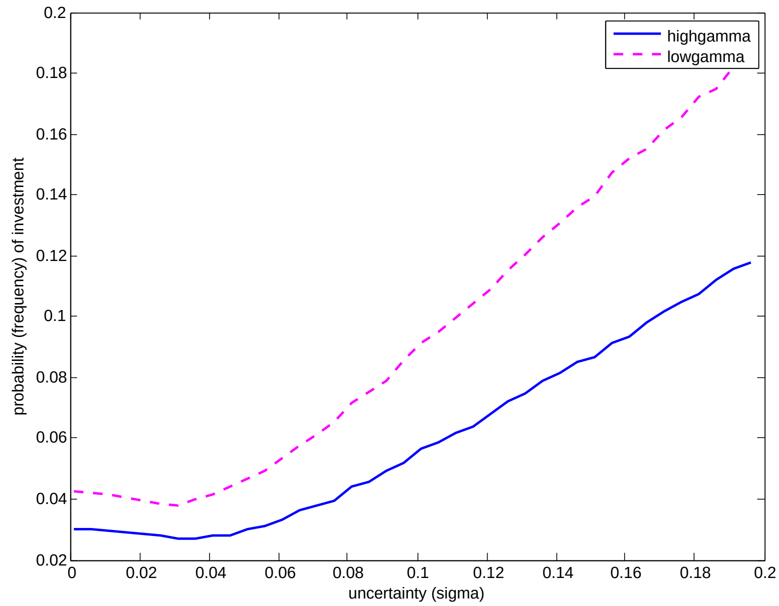
Notes: Figure 1.2 illustrates the dynamics of z — the ratio of household current capital to optimal capital level adjustments.

Figure 1.3: The Dynamics of Household Capital Adjustments



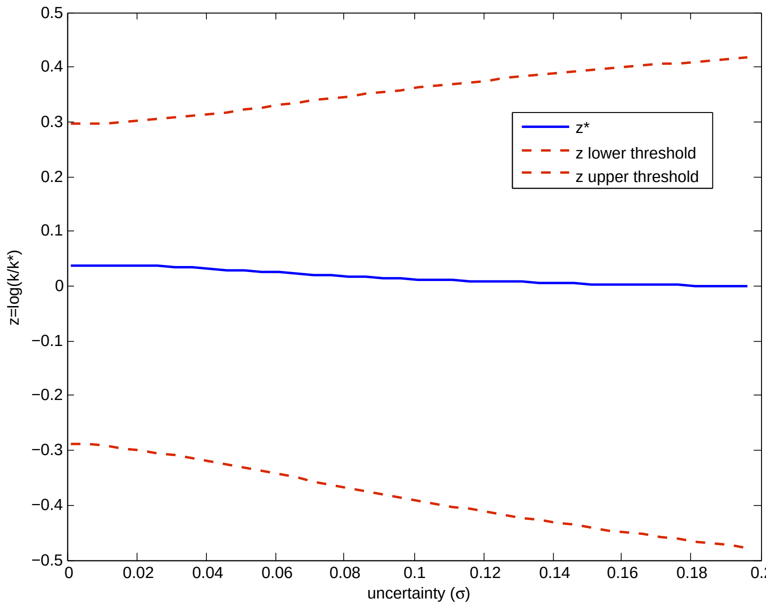
Notes: Figure 1.3 illustrates the dynamics of household capital adjustments.

Figure 1.4: Home Production Technology and Adjustment Frequency



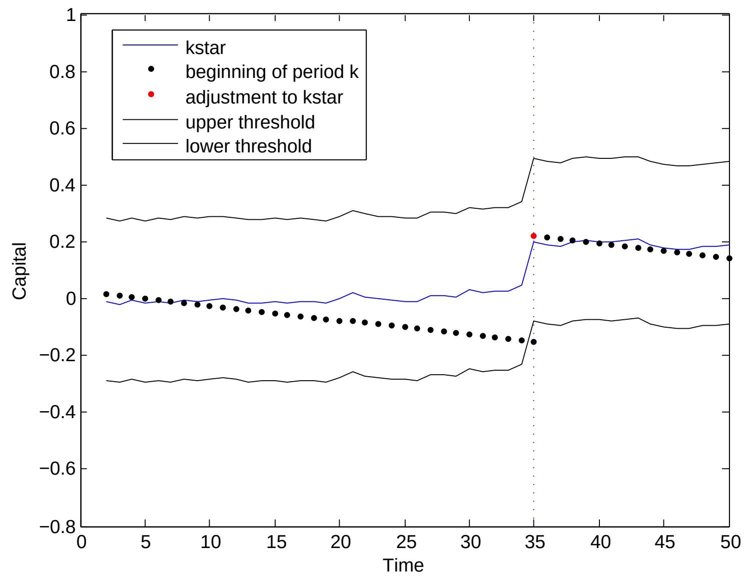
Notes: Figure 1.4 shows (1) an increasing adjustment frequency of durables as income volatility increases. (2) a more labor intensive home production technology causes less frequent adjustment of durables given the same income volatility.

Figure 1.5: Income Uncertainty and Adjustment Boundaries



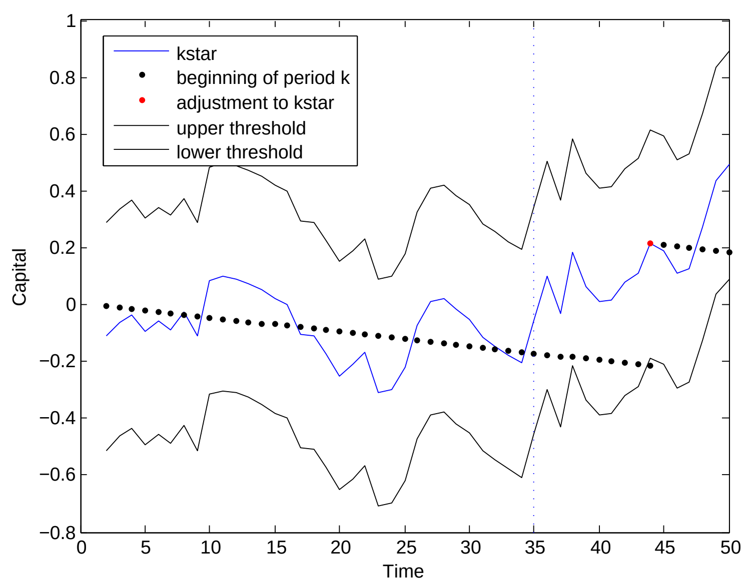
Notes: Figure 1.5 shows a widening inaction band for household capital adjustment as income uncertainty increases.

Figure 1.6: Response to Shocks - Low Uncertainty



Notes: Figure 1.6 shows the effect of a shock under low uncertainty.

Figure 1.7: Response to Shocks - High Uncertainty



Notes: Figure 1.7 shows the effect of a shock under high uncertainty.

Table 1.1: Descriptive Statistics - CHNS

Variables	Obs	Mean	Std. Err.	Min	Max
A. Demographic Variables					
Age	4056	45.77	7.66	25.29	58.99
Middle school edu	4056	0.61	0.49	0	1
High school edu	4056	0.18	0.38	0	1
College edu	4056	0.06	0.24	0	1
Household size	4056	1.87	0.69	1	6
Fraction urban	4056	0.36	0.48	0	1
B. Income Variables					
Annual income	1768	20.91	29.65	1.44	480
Household income	4056	35.37	43.55	0	855
Number of earners	4056	1.81	0.69	1	6
C. Durable Ownership					
Fridge	4056	0.42	0.49	0	1
Washing machine	4056	0.57	0.46	0	1
Electrical cooker	4056	0.54	0.51	0	1
Microwave oven	4056	0.12	0.96	0	1
D. Time Allocation					
Market hours	3812	41.75	19.06	1	119
Home hours	3805	7.68	9.95	0	108
Leisure hours	3805	19.38	13.92	0	120

Note: Annual income and household income are rescaled by 1000.

Table 1.2: Estimated Variance of Permanent and Transitory Shocks to Household Income

	Permanent	Transitory	% of sample
Full Sample	0.019	0.371	N=17487
	(0.002)	(0.010)	
A. Group by Occupation			
Senior professional	0.036	0.176	5.57
	(0.131)	(0.452)	
Junior professional	0.030	0.170	3.02
	(0.061)	(0.284)	
Administrator/manager	0.033	0.337	7.47
	(0.079)	(0.463)	
Office staff	0.038	0.134	3.85
	(0.094)	(0.230)	
Farmer, fisherman, hunter	0.047	0.340	46.27
	(0.124)	(0.420)	
Skilled worker	0.036	0.241	8.5
	(0.077)	(0.437)	
Non-skilled worker	0.039	0.283	9.54
	(0.104)	(0.414)	
Police officer, army officer	0.010	0.150	0.18
	(0.011)	(0.230)	
Ordinary soldier, policeman	0.031	0.216	0.31
	(0.098)	(0.356)	
Driver	0.085	0.350	3.83
	(0.215)	(0.528)	
Service worker	0.061	0.309	6.80
	(0.168)	(0.493)	
Athlete, actor, musician	0.011	0.217	0.18
	(0.028)	(0.318)	

Continued on next page

Table 1.2 – *Continued from previous page*

	Permanent	Transitory	% of sample
Other	0.065	0.465	3.82
	(0.178)	(0.734)	
B. Group by Type of Work Unit			
Government department	0.025	0.151	13.67
	(0.060)	(0.266)	
State service	0.040	0.179	10.21
	(0.090)	(0.304)	
State-owned enterprise	0.034	0.189	5.87
	(0.072)	(0.351)	
Small collective enterprise	0.047	0.329	20.81
	(0.121)	(0.424)	
Large collective enterprise	0.052	0.316	16.49
	(0.141)	(0.449)	
Family contract farming	0.044	0.355	16.70
	(0.124)	(0.419)	
Private, individual enterprise	0.064	0.412	13.82
	(0.181)	(0.651)	
Three-capital enterprise	0.046	0.208	0.36
	(0.103)	(0.350)	
C. Group by Education			
Middle school	0.048	0.318	59.84
	(0.132)	(0.438)	
High school	0.045	0.303	15.72
	(0.113)	(0.516)	
Some college or eqv.	0.033	0.159	5.61
	(0.064)	(0.370)	
D. Group by Age			
Young (below 40 in 2006)	0.086	0.331	32.42
	(0.216)	(0.624)	
Old (above 40 in 2006)	0.038	0.324	67.83

Continued on next page

Table 1.2 – *Continued from previous page*

	Permanent	Transitory	% of sample
	(0.111)	(0.450)	
E. Group by Location			
Urban	0.043	0.258	28.68
	(0.110)	(0.624)	
Rural	0.047	0.317	71.32
	(0.130)	(0.447)	

Note: (1) Variances estimates are based on the decomposition method described in Section II. (2) The first and second columns are the average values of the estimated variance of permanent and transitory income for all households in the specified group. (3) Group designations pertain to the head of household in the beginning wave of the sample. (4) Standard errors are included in the parentheses.

Table 1.3: Summary of Durable Ownerships by Household Characteristics

Ownership Level	HP time (weekly hours)	HH income (1000 RMB)	HH size	Permanent shock to HH income	Transitory shock to HH income
Own Washing machine	8.57	34.57	3.59	0.048	0.287
No Washing machine	7.92	16.14	4.05	0.043	0.322
Own Fridge	8.71	40.35	3.43	0.045	0.275
No Fridge	7.99	0.70	16.67	0.046	0.321
Own Microwave	9.11	60.57	3.17	0.034	0.243
No Microwave	8.17	21.81	3.88	0.047	0.310
Own Electrical cooker	8.05	35.88	3.52	0.047	0.282
No Electrical cooker	8.79	15.41	4.11	0.047	0.316
High Durable	8.54	37.59	3.49	0.047	0.275
Low Durable	8.21	15.16	4.11	0.048	0.319

Note: Durable refers to the sum of ownerships of washing machine, refrigerator, microwave and electrical cooker. High level of durable ownership represents households that own more than average level of appliances.

Table 1.4: Effect of Income Uncertainty on Durable Value - OLS

	Dependent Variables: Durable Value	
	Total Durable Value	Total Durable Value
Explanatory Variable	(1)	(2)
Permanent shock	-53.63	-66.58
	(114.26)	(111.28)
Transitory shock	-119.13***	-141.99***
	(34.02)	(33.69)
Urban	805.73	623.19***
	(34.16)	(33.86)
Age		-5.45***
		(1.87)
Household income		5.44***
		(0.61)
Household size		0.39
		(12.25)
Some Middle School		-286.39***
		(40.53)
High School Equiv.		166.68***
		(51.32)
Some College		869.35***
		(83.74)
Province Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observations	8175	8174

Note: All standard errors are clustered at the household level and are reported in parentheses. Total durable value refers to the sum of monetary value of all four household durables. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.5: Effect of Income Uncertainty on Durable Ownership - Probit

	Dependent Variables: Durable Ownership							
	Washing Machine		Fridge		Microwave		Electrical Cooker	
Explanatory variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Permanent shock	0.131	0.092	-0.040	-0.026	-0.536**	-0.571**	0.069	0.048
	(0.104)	(0.106)	(0.110)	(0.112)	(0.244)	(0.286)	(0.111)	(0.110)
Transitory shock	-0.134***	-0.156***	-0.194***	-0.196***	-0.176***	-0.187***	-0.134***	-0.163***
	(0.029)	(0.031)	(0.035)	(0.036)	(0.063)	(0.134)	(0.063)	(0.034)
Urban	0.872***	0.762***	1.081***	0.917***	1.054***	0.867***	0.569***	0.430***
	(0.031)	(0.033)	(0.031)	(0.033)	(0.042)	(0.046)	(0.033)	(0.035)
Age		-0.144***		-0.004**		-0.006**		-0.009***
		(0.002)		(0.002)		(0.003)		(0.002)
Household income		0.009***		0.009***		0.005***		0.009***
		(0.001)		(0.001)		(0.001)		(0.001)
Household size		-0.012		-0.090***		-0.094***		-0.062***
		(0.011)		(0.014)		(0.020)		(0.013)
Married		0.178***		0.191***		-0.027		0.295***
		(0.052)		(0.059)		(0.082)		(0.057)
Some middle school		-0.082***		-0.182***		-0.448***		0.047
		(0.034?		(0.036)		(0.056)		(0.037)
Some high school		0.232***		0.289***		0.070		0.317***
		(0.044)		(0.046)		(0.065)		(0.048)
Some college		0.986***		1.299***		0.737***		0.786***
		(0.115)		(0.111)		(0.085)		(0.115)
Province Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	12317	12317	12310	12310	12298	12298	12309	12309

Note: All standard errors are clustered at the household level and are reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.6: Effect of Income Uncertainty on Durable Investment - Probit

	Dependent Variables: Durable Purchase							
	Washing Machine		Fridge		Microwave		Electrical Cooker	
Explanatory variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Permanent shock	-0.041	0.068	0.099	-0.024	0.123	-0.118	0.096	0.125
	(0.183)	(0.182)	(0.204)	(0.214)	(0.720)	(0.808)	(0.218)	(0.214)
Transitory shock	0.143***	0.170***	0.098**	0.088*	0.400***	0.517***	0.131***	0.146***
	(0.052)	(0.054)	(0.056)	(0.049)	(0.136)	(0.134)	(0.053)	(0.056)
Durable stock	-0.856***	-0.872***	-0.837***	-0.817***	-0.868***	-0.860***	-0.476***	-0.463***
	(0.076)	(0.076)	(0.084)	(0.086)	(0.175)	(0.179)	(0.064)	(0.066)
Urban	-0.709***	-0.602***	-0.861***	-0.687***	-0.659***	-0.572***	-0.350***	-0.223***
	(0.062)	(0.067)	(0.065)	(0.069)	(0.110)	(0.117)	(0.056)	(0.059)
Age		0.025***		-0.002		0.001		0.005
		(0.004)		(0.004)		(0.009)		(0.004)
Household income		-0.005***		-0.005***		-0.004***		-0.005***
		(0.001)		(0.001)		(0.001)		(0.001)
Household size		0.071***		0.142***		0.179***		0.077***
		(0.021)		(0.025)		(0.057)		(0.021)
Married		-0.273***		-0.246*		0.153		-0.142
		(0.110)		(0.131)		(0.233)		(0.111)
Some middle school		0.128*		0.329***		0.582***		0.008
		(0.070)		(0.079)		(0.145)		(0.069)
Some high school		-0.079		-0.024		0.268*		-0.173**
		(0.086)		(0.093)		(0.160)		(0.086)
Some college		-0.549***		-0.822***		-0.179*		-0.617***
		(-0.167)		(0.171)		(0.168)		(0.145)
Province Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3772	3772	2817	2817	769	769	3794	3794

Note: All standard errors are clustered at the household level and are reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.7: Differential Effect of Household Income Change on Durable Investment

Dependent Variables: Durable Purchase	
Explanatory Variable	(1)
High σ_ϵ^2	0.134**
	(0.059)
ΔIncome	0.016***
	(0.006)
High $\sigma_\epsilon^2 \times \Delta$Income	-0.013*
	(0.008)
Durable stock	-0.696***
	(0.103)
Urban	-0.120**
	(0.053)
Province Fixed Effects	Yes
Year Fixed Effects	Yes
Observations	3195

Note: All standard errors are clustered at the household level and are reported in parentheses. Occupation effects are controlled for but not reported due to space limit. Durable Purchase is a dummy that equal to 1 if any of the four durables is purchased. Durable stock is the sum of all individual durable stocks.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.8: Differential Effect of Appliance Price Rebate on Durable Investment

Dependent Variables: Durable Purchase		
	High σ_ϵ^2(¿25% percentile)	Low σ_ϵ^2 (¡25% percentile)
Explanatory Variable	(1)	(2)
Price rebate	0.191**	0.397***
	(0.103)	(0.145)
Durable stock	-0.783***	-0.719***
	(0.126)	(0.180)
Province Fixed Effects	Yes	Yes
Year Fixed Effects	Yes	Yes
Observations	1931	1265

Note: All standard errors are clustered at the household level and are reported in parentheses. Durable Purchase is a dummy that equal to 1 if any of the four durables is purchased. Durable stock is the sum of all individual durable stocks.
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 1.9: Parameter Values

Parameter	Symbol	Value
Discount factor	β	0.8
Coefficient of Cobb-Douglas consumption	α	0.7
Coefficient of home production technology	γ	0.7
Author defined parameter	$\theta = (1-\alpha)(1-\gamma)$	0.1
Capital depreciation rate	δ	0.005
Mean growth rate of expenditure	μ	0.005
Fixed adjustment cost	ϕ	0.02

1.6 Model Derivation

The following derivation presents the detail on solving the household intra-temporal problem for h while treating k as given.

Give k, the household's intra-temporal problem now becomes:

$$\begin{aligned} &\max_h \; c_m^{\alpha} c_h^{1-\alpha} \\ \text{subject to} \quad & c_m + vk + wh = q \\ & c_h = h^{\gamma} k^{1-\gamma} \end{aligned}$$

This problem can be rewritten as:

$$\max_h \; (q - vk - wh)^{\alpha} (h^{\gamma} k^{1-\gamma})^{1-\alpha} \tag{1.1}$$

The solution with fixed k is:

$$h = \frac{1}{w} \frac{1}{\frac{\alpha}{1-\alpha}\frac{1}{\gamma} + 1} (q - vk)$$

After obtaining the solution for h with fixed k, we are able to derive the total consumption c as a function of total expenditure q and the ratio of household durables stock level k to the optimal stock level k^* in a given time period.

Substituting h into c, we obtain the following expression for total consumption:

$$c = \text{constant terms} \cdot \frac{1}{w^{\gamma(1-\alpha)}}(q - vk)^{(1-\theta)}k^{\theta}$$

where $\theta = (1-\alpha)(1-\gamma)$

Recall from the optimal condition (1.20):

$$k^* = \frac{q}{v}(1-\alpha)(1-\gamma) = \frac{q\theta}{v}$$

It can be shown by simple algebra that

$$\begin{aligned} c &= k^* \frac{c}{k^*} = \frac{q\theta}{v}\frac{c}{k^*} \\ &= \frac{\text{const}}{w^{\gamma(1-\alpha)}}\frac{\theta}{v}v^{1-\theta}q(\frac{1}{\theta} - \frac{k}{k^*})^{1-\theta}(\frac{k}{k^*})^{\theta} \\ &= \text{constant} \cdot q(\frac{1}{\theta} - \frac{k}{k^*})^{1-\theta}(\frac{k}{k^*})^{\theta} \\ &= \text{constant} \cdot q(\frac{1}{\theta} - \frac{k}{k^*})^{1-\theta}(\frac{k}{k^*})^{\theta} \end{aligned}$$

Take logarithm of c and drop the constant terms gives us the household utility at date t:

$$\ln c_t = \ln q_t + (1-\theta)\ln(\frac{1}{\theta} - \frac{k_t}{k_t^*}) + \theta \ln \frac{k_t}{k_t^*} \tag{1.2}$$

Chapter 2

Durable Ownership and Time Allocation: Evidence from China's "Home Appliances to the Countryside" Rebate

2.1 Introduction

The marked rise in women's labor force participation over the twentieth century has been well-documented. Correlates of this change include economic factors (Goldin [1995]), socio-cultural norms and attitudes (Fernández et al. [2004]) and new technologies (Goldin and Katz [2000], Greenwood et al. [2005], de V. Cavalcanti and Tavares [2008], Coen-Pirani et al. [2010]). Much of our knowledge concerning the catalyst of increased female labor force participation (LFP) comes from studies based on data from developed countries. These insights may not be directly applicable to settings where market imperfections, social norms, or institutions moderate womens' incentives and constraints to enter the labor market.

In this paper, we turn to a developing country context to assess one particular hypothesis about the drivers of increased female work time– adoption of durable good technologies. Using panel data on Chinese households, we investigate whether increased ownership of home production technologies like fridge and washing machines reduced housework and boosted employment among Chinese women. This mechanism underlying increased female LFP is in the spirit of Greenwood et al. [2005] "engines of liberation" hypothesis where appliance adoption generates labor savings in home production and spurs an increase in market labor supply.

Identifying the impact of durable adoption of time allocation and labor force participation would typically be riddled with endogeneity problems. We circumvent these issues by exploiting plausibly exogenous variation to durable price generated by the Chinese government's "Home Appliances (Going) to the Countryside" (HAGC) rebate program. Starting in 2007, households residing in certain geographical areas were offered a thirteen percent rebate in specific durable goods categories. Over the next five years, different geographies and durable categories became eligible for the rebate. We exploit the cross-sectional and temporal variation created by the promotion as a shock to the price of appliances which boosted their ownership propensity among eligible or "treated" households. Using this price shock as an instrument for durable ownership, we then estimate its impact on home production and market work time.

We organize the evidence within a tractable theoretical framework. Building upon the standard home production framework (surveyed in its various applications in Aguiar et al. [2012]), we formulate a model that allows us to obtain comparative statics predicting the effects of durable goods adoption on time allocation. We show that if the elasticity of substitution between home and market goods in the household's utility is sufficiently low, then appliance adoption leads to a reduction in home work. A second feature of the model is it allows us to distinguish between a wife's and husband's time use. We show that when the wife's labor is a closer substitute to household capital services than the husband's labor, she experiences a stronger labor-saving effect of appliance adoption, which in turn boosts her labor market supply.

Turning to the empirical results, we first confirm that the rebate had a significant effect on prices, ownership of appliances and time reallocations. Using the policy as a first-stage instrument, we test the prediction of the model regarding LFP of married female in the household. Consistent with the theoretical framework, the data reveals that following the rebate, appliance adoption significantly reduced home production time and increased market working time, as well as significantly increased the predicted probability of married women LFP [1].

[1] On average, ownership of a durable such as fridge, washing machine or motorbike decreased time spent

The idea of durables as "engines of liberation" has been explored empirically in a limited way and with mixed results. Using aggregate country-level data from seventeen OECD countries, de V. Cavalcanti and Tavares [2008] finds that a twenty percent decrease in the relative price of appliances leads to an increase in participation of between two and three percent. Using U.S. Census data, Coen-Pirani et al. [2010] find the diffusion of household appliances accounts for about forty percent of the observed increase in married womens' labor force participation rates during the 1960s. In contrast to these two papers, Cardia [2010], using U.S. Census data and relying on fixed-effects estimation, finds evidence weighing in against durables as a significant drivers of womens' LFP again. We improve on these work methodologically by using panel data in conjunction with plausibly exogenous shocks to durable prices. Importantly, since we actually have micro, individual-level data on time-use, we are able to document the effects of durable-ownership on time allocations thus providing direct evidence in support of the home production channel formalized in our model and underlying the model of Greenwood et al. [2005].

More generally, we also contribute to stream of literature highlighting various correlates of increased women's LFP. These include how technologies that lowered childbearing (Goldin [1995]) and infrastructural (Dinkelman [2011]), evolving social preferences (Fernandez et al. [2002]), economic factors (Goldin [1995]) as well as reduced social norms (Goldin [1995], Mammen and Paxson [2000]).

The rest of the paper is as follows. Section 2.2 specifies the home production model and presents the theoretical predictions. Section 2.3 introduces China's "Home Appliance to the Countryside" Rebate program. Section 3.2 describes the data and empirical strategy. Section 2.5 presents the empirical findings. Finally, section 2.6 concludes.

2.2 Theoretical Framework

In this section, we formulate a simple theoretical framework that illustrates how a reduction in the prices of home appliances induces households to invest in these technologies and generates a reallocation from home work time to market work time. We provide conditions under which this mechanism is especially important for female labor supply. The model belongs to a broader class of models first pioneered by Becker [1965] and Gronau

in housework by 7 hours per week for the female. Time spent in market work increased by 19-20 hours per week for the female and 7 hours per week for the male.

[1976] where the household consumes both market-produced goods and home-produced goods and allocates time among market work, home work and leisure (see the recent survey by Aguiar et al. [2012]).

2.2.1 Model Setup

Consider a unitary household model where there are two household members: husband and wife, denoted $i \in \{H, W\}$. Household utility depends on household consumption c and the leisure time of each household member l_i:

$$U = \ln(c) + \sum_{i \in \{H,W\}} \ln(l_i) \tag{2.1}$$

As in recent models of home production (see Aguiar et al. [2012]), household consumption is a CES aggregate of market goods (x^m) and home goods (x^h):

$$c = \left[(x^m)^\theta + \left(x^h \right)^\theta \right]^{\frac{1}{\theta}} \tag{2.2}$$

where x^m represents goods purchased in the market and x^h represents goods produced at home (measured in the same units as market-purchased goods). The parameter $\theta \leq 1 (\theta \neq 0)$ is the elasticity of substitution between market consumption and home consumption. While this functional form nests the case of perfect substitution ($\theta = 1$) often studied in the earlier literature (see for example Gronau [1977]), the assumption that home and market goods are not perfect substitutes ($\theta < 1$) is important in explaining the time-saving effect of appliances, as we will discuss below.

Home goods are produced by the household using labor and capital. We describe the home production process by using a parsimoniously parameterized function of the three inputs: labor inputs including home production time for both husband and wife (h_H and h_W), and capital input, the household stock of appliances k.[2] The standard modeling choice in the literature is a Cobb-Douglas specification (as in most of the models surveyed by Aguiar et al. [2012]). However, in order to explain the differential impact of appliance adoption on the household members' labor supply, it is necessary to allow the elasticity of

[2]To simplify we consider only one single appliance in our model and treat it as a continuous variable, $k \in \mathbb{R}^+$. Qualitatively similar results obtain from the model with a discrete appliance variable, $k \in \{0, 1\}$, and are available from the authors upon request.

substitution between labor and capital to differ across different labor inputs. Therefore we consider the following nested CES technology:

$$x^h = \left[(h_W)^\sigma + (h_H^\rho + k^\rho)^{\frac{\sigma}{\rho}} \right]^{\frac{1}{\sigma}} \tag{2.3}$$

where σ and ρ give the elasticity of substitution between husband's home production time, wife's home production time and durable appliance. Both σ and ρ are in $(-\infty, 1)$. If either σ or ρ equals zero, the corresponding nesting is Cobb-Douglas. Values of σ or ρ greater than zero indicate greater substitutability than in the Cobb-Douglas case. Note that the elasticity of substitution between durable appliance and the wife's home work is $\frac{1}{1-\sigma}$, and the elasticity of substitution between durable appliance and the husband's home work is $\frac{1}{1-\rho}$. With this formulation, we allow different degrees of substitutability between household capital and male labor and female labor respectively. Specifically, when $\sigma > \rho$ household capital is a closer substitute for the wife's labor relatively to the husband's labor.

The household uses labor and non-labor income to purchase market consumption goods and appliances. The household faces a budget constraint given by:

$$\sum_{i \in \{H,W\}} w_i n_i + v = x^m + pk \tag{2.4}$$

where n_i is market work hours of household member i. Prices are expressed in real terms, i.e. they are relative to the price of market consumption goods: w_i is the real wage of member i, p is the real rental price of household capital and v is real non-labor income.

In addition, each household member faces a time allocation constraint:

$$l_i + n_i + h_i = 1 \quad i \in \{H, W\} \tag{2.5}$$

2.2.2 Predictions of the Model

We use this home production model to obtain predictions about the effects of a reduction in appliance prices on household time allocation. To generate the predicted comparative statics, we solve the model numerically. Appendix provides the first-order conditions of the model that we use to compute the optimal solution. First, we look at the case where there are no differences between household members. The parameters for this exercise are: $\theta = 0.2$, $\sigma = \rho = 0.7$ $w_H = w_W = 1.15$, $v = 0$. The main conclusion is robust to changes in the parameters as long as an interior solution exists. Figure 2.2 plots the optimal amount of household capital as a function of the appliance price. Figure 2.2 depicts a clear negative relation and indeed for a large range of parameter values household capital behaves as a normal good. Thus the model predicts that as appliance prices drop households invest in more appliances.

Figures 2.3a and Figures 2.3c illustrate how time use is affected by the appliance price. As the price of appliances falls and household capital increases, time is reallocated from home work to market work. To understand the underlying mechanism, first note that this result is different from what standard production theory would suggest: since labor and capital are generally not perfect substitutes in production of home goods, one would expect that capital and labor input are positively related. This is certainly the case when home goods and market goods are perfect substitutes: $\theta = 1$. In this case, the optimality condition (2.1) reduces to:

$$\frac{\partial x^h}{\partial h_i} = w_i \; i \in \{H, W\} \tag{2.6}$$

since under perfect substitution we have $\frac{\partial c}{\partial x^h} = \frac{\partial c}{\partial x^m}$. Equation (2.6) is the standard home work supply rule from the earlier home production literature (see for example Gronau [1977]) and it states that home work hours are chosen so that its marginal product is equal to the given real wage. Because labor and capital are not perfect substitutes, an increase in the capital stock raises labor productivity: $\frac{\partial^2 x^h}{\partial h_i \partial k} > 0$. Then the law of diminishing marginal product of labor implies that when the household capital stock increases, labor input in home production also has to go up in order to satisfy (2.6). In this environment, appliance adoption induces an increase in home work.

To explain the time-saving effect of household capital, it is necessary that home goods and market goods have a sufficient degree of complementarity, i.e. θ has to be sufficiently low (unlike the previous case where $\theta = 1$). When home goods and market goods are not close substitutes, it is optimal for the household to consume a mix of both. In this case, when the household capital stock increases and home work becomes more productive, it is optimal to reallocate some of the time saved from home production to market work. This adjustment allows both home consumption and market consumption to increase at the same time, maximizing household utility.

More importantly, the model allows for a differential effect on the household members' labor supply. To see this, we solve the model when the wife's labor is a closer substitute to household capital services than the husband's labor:

$$\sigma > \rho \tag{2.7}$$

In order to reproduce a more realistic situation we also assume a gender gap in wages, although this is not necessary to generate differential responses of home work to appliance adoption. Thus the new parameters chosen are: $\theta = 0.2$, $\sigma = 0.8$, $\rho = 0.6$ $w_H = 1.3$, $w_W = 1$, $v = 0$. Figures 2.3b and 2.3d illustrate how the appliance price differentially affects time use for the two household members. Figure 2.3b shows that there is a sharper decrease in the wife's home work time as the appliance price falls. In Appendix B we provide a general proof of the result that condition (2.7) implies a sharper decrease in the wife's home work time without resorting to numerical methods (in particular, see equation (2.11)). As before, the reduction in home work time spurs an increase in market work for each individual, as shown by Figure 2.3d. Again, the wife's market work increases more as the appliance price falls while the husband's market work curve is flatter.

To summarize, the model makes the following theoretical predictions:

1. *A reduction in appliance prices induces an increase in appliance adoption.*
2. *If the elasticity of substitution between home goods and market goods is sufficiently low, adoption causes a reduction in house work and an increase in market work for at least some of the household members.*
3. *When the wife's labor is a closer substitute to household capital services than the husband's labor, then the wife experiences a larger decrease (increase) in home work (market work) than the husband.*

2.3 Background: China's "Home Appliance to the Countryside" Rebate

The model in the previous section predicts that adoption will change time allocation in the household. We seek to establish causality and the key to our identification strategy is to leverage the exogenous price variation generated by the "Home Appliances

Going to the Countryside" (HAGC) rebate. HAGC was a five-year, government-sponsored promotion aimed at stimulating consumption of home appliances in rural China. Households were entitled to rebates of thirteen percent when they bought certain categories of durable goods. Each household could buy up to two products within each category. In December 2007 the policy was first introduced in Shandong, Henan, Sichuan provinces and the eligible categories were television sets, refrigerators, mobile phones or washing machines. One year later (December 2008) the program was extended to Inner Mongolia, Liaoning, Dalian, Heilongjiang, Anhui, Hubei, Hunan, Guangxi, Chongqing, and Shanxi. Finally in February 2009, the policy was extended to the whole country, and the number of subsidized products was increased to include motorcycles, computers, water heaters, and air conditioners. Each province could choose two of these four extra products to promote ("4+2 Policy"). [3] Figure 2.1a and Figure 2.1b show the timeline of rebates across provinces and categories. In the empirical analysis, we focus on three durables that came under the purview of HAGC– washing machine, fridge (both part of Phase 1) and motorbike (Phase 2).

HAGC has been regarded to have boosted sales considerably, with over 300 million units sold over the five-year period and sales recording double-digit growth. In 2011, the cumulative sales of HAGC commodities reached 405 billion yuan (about US$64 billion) and the total amount of subsidies were 46 billion yuan (about US$7.3 billion).

2.4 Methodology and Data

2.4.1 Data

The data are drawn from the *China Health and Nutrition Survey* (CHNS)[4]. The survey has a detailed document on time use at individual level and durable appliance ownership at household level. Observations are across nine provinces that vary substantially in geography, economic development, and public resources. This survey was conducted in 1989, 1991, 1993, 1997, 2000, 2004, 2006 and 2009. Our sample is drawn from five waves of

[3] The price ceilings for these products were RMB3500 for color TVs, RMB2500 for refrigerators (including freezers), RMB1000 for cell phones, RMB2000 for washing machines, RMB3500 for computers, RMB2500 for wall-mounted air-conditioners and RMB4000 for floor-stand air-conditioners.

[4] The survey is a collaborative effort between the Carolina Population Center at the University of North Carolina at Chapel Hill and the National Institute of Nutrition and Food Safety at the Chinese Center for Disease Control and Prevention. Details are at http://www.cpc.unc.edu/projects/china

the CHNS data, namely wave 2000, 2004, 2006 which are before-rebate periods, and wave 2009 and 2011 which are after-rebate period. Our sample includes both urban and rural households, though urban areas are not included by the promotion, it serves as a great control group in our experiment. Our baseline analysis involves a sample of households with household heads who are urban or rural residents, married, between age 25 to age 59, not students, and not retired.[5] We drop the small number of households reporting zero or missing household income, or with missing education or age information. We include households in all five waves in which they appear in the survey and satisfy all our requirements. To limit the effects of extreme observations, we also drop some outlier observations on time use and individual annual income. Therefore, our final sample is an unbalanced panel consisting of 4056 households.[6]

Table 2.1 provides key descriptive statistics of the sample. The sample contains individuals between 25 and 60 years old. The median size of the household is two people. The majority of individuals (70%) are from rural areas. There is considerable heterogeneity in the level of education, income and working status in the population. The data provide information on household durable goods. In particular, we look at whether the household owns a fridge, a washing machine and one or more motorcycles. There is substantial variability in these variables. To measure household capital, we construct an index given by the sum of these three variables.[7]

We study how individuals allocate their time by computing the number of hours per week that a person spends in different activities and classify them in three categories: market work, home work and leisure. Home production time is calculated as hours per week spent on taking care of children, cleaning the house, doing laundry, cooking, and doing grocery shopping. Market time is defined as hours per week spent on primary occupation. Leisure time is defined as the sum of hours spent per week on sedentary activity and physical activity. The average individual in the sample spends 42 hours per week in market work, 6 hours per week in home work and 10 hours per week in leisure activities. Around one tenth

[5]One reason to exclude retired individuals in our sample is that older individuals or retired individuals tend to have very different patterns in time allocation: spend significantly more time in home work than working individuals, possibly due to their low opportunity cost. Another reason is that since retired individuals' time share for market work is essentially zero, it would create biased estimation if we intend to investigate the time-reallocation margin from home to the market.

[6]The sample is unbalanced also because of new respondents introduced into the survey, old respondents moved out of the survey, and transitions of household members into retirement or aging.

[7]Our choice for the three appliances are based on both the rebate program coverage and the consideration of its usage related to home production productivity.

of the individuals are engaged in childcare at home.

2.4.2 Estimation Strategy: Difference-in-Differences

We estimate the following specification which compares changes in our outcomes of interest of durables that are covered by rebate and not covered by rebate. The specification is as follows:

$$p_{it} = \text{Fixed effects} + \lambda(d_t \times Treat_i) + \mu_{it} \tag{2.8}$$

In the equation above, our main interest in on the parameter λ which estimates the effect of the rebate $(d_t \times Treat_i)$ on durable price p_{it}. d_t is a dummy which is equal to 1 if the observation is from wave 2009 (post). $Treat_i$ is a dummy which is equal to 1 if the appliance is covered by the rebate program.

The second reduced-form relationship we examine is the effect of rebate on durable ownership. Applying a similar DID estimation strategy, we compare the changes in durable ownerships for affected households pre-rebate (2000, 2004 and 2006) and after-rebate (2009 and 2011) to unaffected households controlling for time and household fixed effects as well as other time-varying covariates. The specification is as follows:

$$k_{it} = \text{Fixed effects} + X'_{it}\beta + \delta(d_t \times Treat_i) + \epsilon_{it} \tag{2.9}$$

In the equation above, our main interest in on the parameter δ which estimates the effect of the rebate $(d_t \times Treat_i)$ on k_{it} (household capital/durable ownership). k_{it} will be an "index" which is the sum of all three durables (so, maximum is 3 if fridge, washing machine and motorcycle are all owned and minimum is 0 if none is owned). d_t is a dummy which is equal to 1 if the observation is from wave 2009 (post). $Treat_i$ is a dummy which is equal to 1 if the observation resides in certain rural area that is covered by the rebate program. X_{it} is a vector of all the control covariates, including age, education and household income. The identification assumption here is that there are no systematic difference in the control (no rebate) and treated (rebate) groups prior to treatment. Later, we will provide support for this assumption.

The third relationship that is of great interest is to test the differential impact of the rebate on time allocation for wife and husband. We run the following OLS regression for home work hours for wife and husband separately:

$$h_i = \text{Year Fixed effects} + X_{it}'\beta' + \delta'(d_t \times Treat_i) + \upsilon_{it} \tag{2.10}$$

Our main interest is in estimating the parameter δ', that captures the effect of the rebate program on home work time. A similar regression is estimated for which market work is the dependent variable[8].

2.5 Results

2.5.1 DID Assumption Revisited

Firstly we use a panel of differences-in-differences tables to show raw comparison of means for the effect of the rebate on durable ownership[9]. Table 2.2 shows that there is an increase in mean household durable ownership, and the increase is around 0.17 units. On the time allocation aspect, wife's home production time for those affected households before and after the rebate has dropped 2.88 hours per week compared to unaffected households shown by Table 2.8 upper panel. In contrast, husband's home production time for those affected households has dropped only 0.22 hours per week as shown by Table 2.8 lower panel. Similar comparisons for market work time are shown by Table 2.9. Wife's market work time for those affected households before and after the rebate has increased 1.44 hours per week compared to unaffected households. In the meanwhile husband's market work time for those affected households has dropped by 0.81 hours per week.

A key identifying assumption for the DID specification is that there are no differing ownership trends between control and treated groups prior to the rebate. Figure 2.4 graphs average ownership for eligible and ineligible households in the years before and after the rebate. We see that prior to 2006 control and treated households have a parallel trend in durable ownership and afterwards there is an uptick in ownership for families who got the rebate.

[8] We also try to trace the direct impact of ownership on time allocation by doing an instrumental variables analysis where endogeneity problem is taken care of by using the HAGC rebate as a natural experiment. The direction of the estimates is similar to the OLS analysis but the magnitudes differ considerably. We report the IV results in Appendix, see Table2.10 and Table 2.11.

[9] We do a similar analysis for hours, results are in the Appendix. See Table 2.8 and 2.9.

2.5.2 The Impact of Rebate on Durable Prices, Ownership and Time

A direct test to the effect of the HAGC policy is to use durable price as an outcome variable and examine the different responses of durable prices for those under rebate and not covered by rebate. Table 3.1 shows the effect of the HAGC policy on prices of different durable categories. As expected, prices fall significantly for the durables that were subject to the policy (Table 2.3a) and eligible durables remain unaffected (Table 2.3b). Results are significant at 1%, 5% and 10% level.

The DID estimates from estimation equation (2.9) are presented in Table 2.4. The probability that a household owns a washing machine increases significantly by 6% if the household receives a price rebate (columns (1)). The probability of owning a fridge or a motorcycle also increases significantly, by about 8% (columns (2) and (3)). Overall, the rebate seems to have a positive and significant causal effect on durable ownerships (shown in columns (4) and (5)).

Turning to the OLS estimates of the effect of the HAGC policy on time allocation between home work and market work, we find that the rebate does significantly reduced home work time and significantly increase market work time for both wife and husband, but the magnitude is quite different. The estimates are significant at 1% level. Table 2.5 reproduces the results for home work, obtained from estimating equation (2.10). Comparing estimates from column (1) and (2), home appliance rebate has a much stronger effect on reducing wife's home work time. This may imply that wife's labor is a closer substitute to household appliance than the husband's labor, which is consistent with our theory prediction. Table 2.6 presents the OLS estimates of the effect of household appliances rebate on hours of market work. Again, we control for province fixed effects and year fixed effects, and a number of observables. Results show that with appliances rebate, wife's market hour increases more than the husband's, which coincides with the previous finding that the greater reduction in wife's home work has been reallocated to market work.

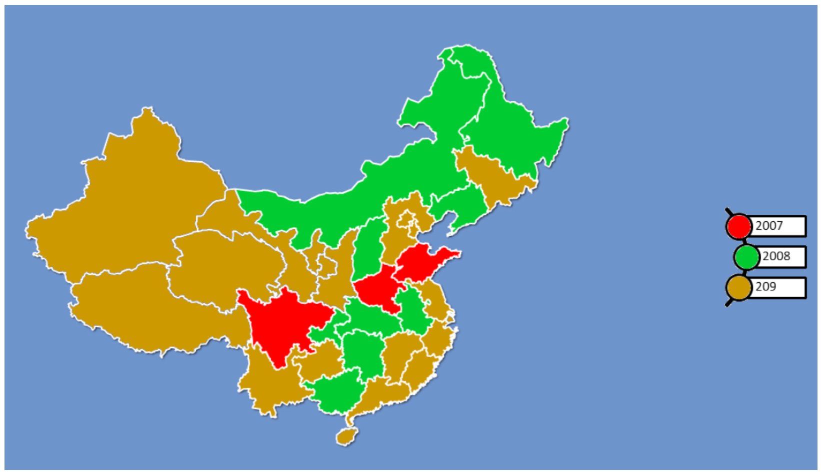
The IV probit test results on female LFP are reported in Table 2.12. The coefficients on household appliances are positive and significant at 1% level, which indicates an increase in the ownership of home appliance leads to a significant increase in the predicted LFP probability for married women. Results hold for each appliance as well as the appliance index. We also find significant positive correlation between college education and female LFP, and significant negative effects of age, middle school education, high school education, and household income on female LFP.

2.6 Conclusions

In our analysis, we find durable goods such as washing machine, fridges and motorbikes led to considerable reductions in home production time and boosts to market work time, particularly for female household members. Moreover the adoption of household durable appliances increases female labor force participation. Given the rapid penetration of labor-saving appliances among the burgeoning middle-classes in emerging and developing markets, this particular channel is particularly relevant for policymakers and researchers interested in the drivers of female labor-force participation. Reductions in time-consuming housework for females also have implications for welfare-enhancing outcomes like female literacy and schooling (Ilahi and Grimard [2000], Nauges and Strand [2011], Sekhri [2013] as well as better health and education for children (Mokyr [2000], Lewis [2012]).

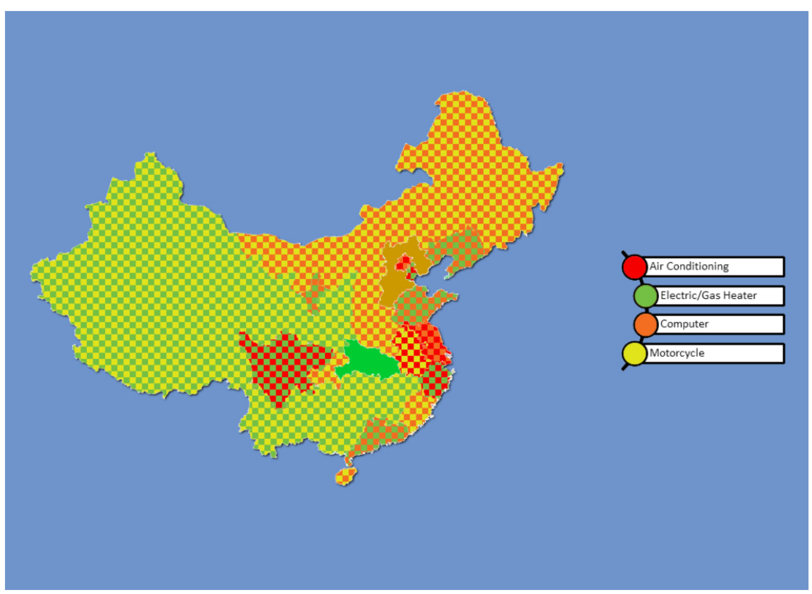
2.7 Figures and Tables

Figure 2.1: China's Home Appliances to the Countryside Rebate



(a) Timing of Phase 1 Rebate (TV, WM, Fridge, Cellphone)

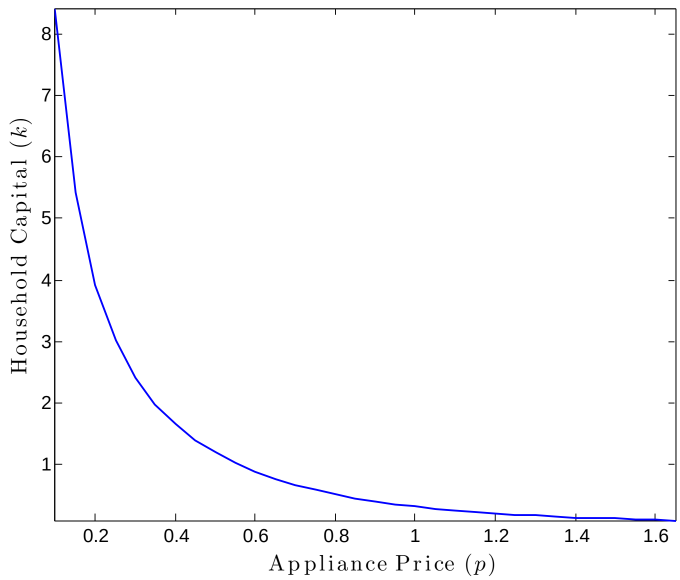
Notes: Phase 1 refers to rebate on four appliances (TV, washing machine, fridge, cellphone) from 2007 to 2009 across difference provinces.



(b) Phase 2 Rebate: Two appliances chosen per province in 2009

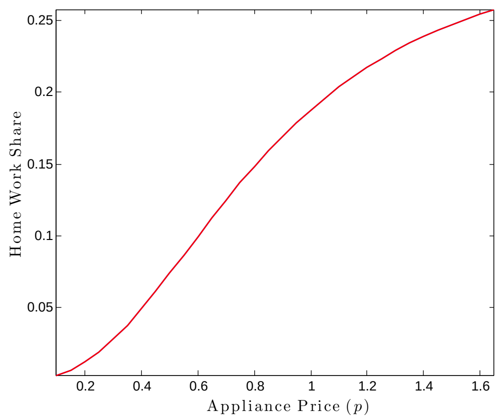
Notes: Phase 2 refers to rebate on two appliances chosen by each province from motorcycles, computers, water heaters, and air conditioners in 2009.

Figure 2.2: Appliance Price and Household Capital

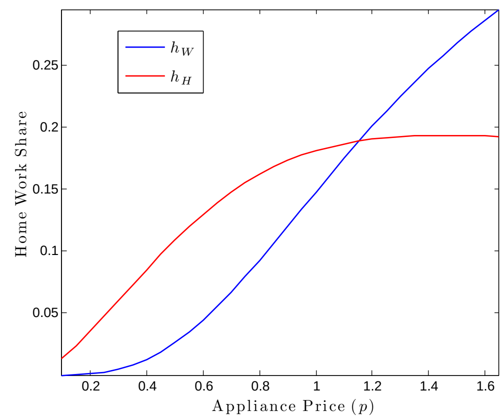


Notes: Figure 2 shows a clear negative relation between the optimal amount of household capital and the appliance price.

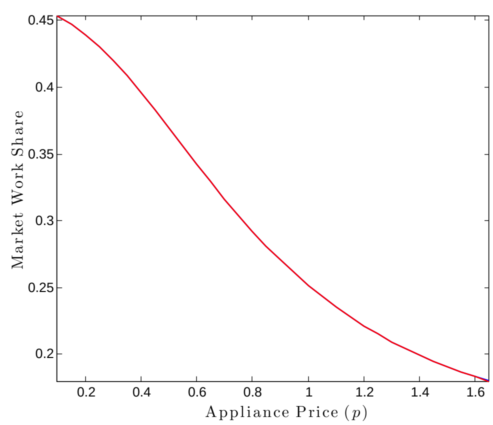
Figure 2.3: Appliance Price and Time Allocation



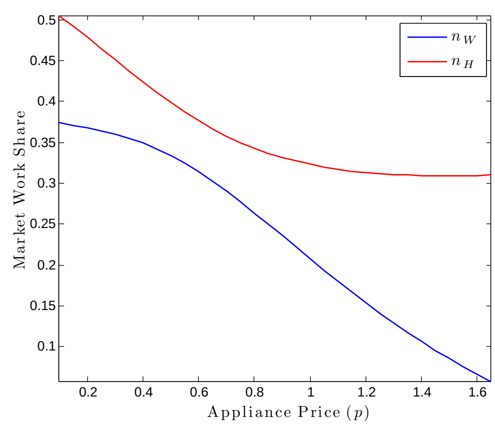
(a) Appliance price and home work time:
Baseline Case – No gender difference



(b) Appliance price and home work time:
With gender difference

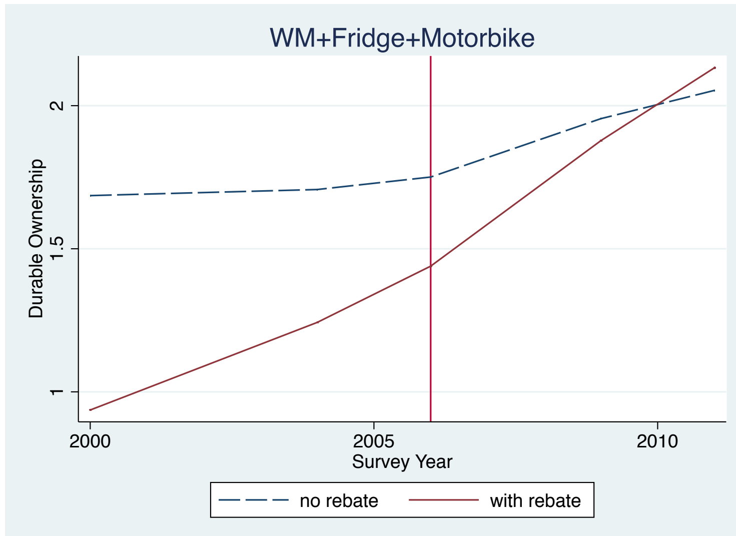


(c) Appliance price and market work time:
Baseline Case – No gender difference



(d) Appliance price and market work time:
With gender difference

Figure 2.4: Trends in Durable Ownership for Control and Treated Groups



Notes: Average durable ownership refers the durable index which include all three appliances (washing machine, fridge, and motorbike). The graph represents the arithmetic mean of durable ownership based on 95% CI by "treatment group".

Table 2.1: Descriptive Statistics - CHNS

Variables	Obs	Mean	Std. Err.	Min	Max
A. Demographic Variables					
Age	8345	45.88	7.77	24.04	58.99
Middle school edu	8345	0.61	0.49	0	1
High school edu	8345	0.17	0.38	0	1
College edu	8345	0.07	0.24	0	1
Household size	8318	3.57	1.17	1	11
Fraction urban	8345	0.29	0.45	0	1
B. Income Variables					
Annual income	3602	21.72	30.55	0.14	580
Household income	8290	36.31	42.89	0	780
Number of earners	8345	2.04	0.81	1	7
C. Durable Ownership					
Fridge	8311	0.57	0.49	0	1
Washing machine	8313	0.70	0.46	0	1
Motorcycle	8306	0.34	0.47	0	1
Total Index	8345	1.61	0.99	0	3
D. Time Allocation					
Market hours	6857	42.75	18.74	1	119
Home hours	8345	6.35	12.04	0	119
Leisure hours	8345	10.06	13.85	0	116
Childcare dummy	5290	0.13	0.35	0	1

Note: Total index refers to the sum of three home appliances ownership for: washing machine, refrigerator and motorbike. Annual income and household income are rescaled by 1000.

Table 2.2: Effect of Rebate on Average Durable Ownership

	Households by Rebate		
Variable	Control (1)	Treat (2)	Difference Treat-Control (3)
Durable Ownership (pre)	1.71	1.18	-0.53
			(-16.71)
Durable Ownership (post)	2.02	1.99	-0.03
			(-0.99)
Change in Mean Ownership	0.31	0.81	0.50
	(10.56)	(30.55)	

Note: Durable ownership refers to the sum of ownerships of three household durable appliances: refrigerator, washing machine and motorcycle. It is a variable between 0 and 3. t-statistics are reported in parentheses.

Table 2.3: HAGC Rebate and Durable Appliance Price

(a) Effect of Rebate on Chosen Durable Appliance Price

	Prices of Durable Appliances (CHOSEN for rebate)			
	Washing Machine	Fridge	Motorcycle	Cell Phone
HAGC	-161.07**	-222.03*	-2526.83***	-652.78***
	(77)	(132)	(746)	(172)
Year FE	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes
Observations	6275	5121	9244	9244

Note: All the above four appliances belong to the HAGC rebate, either in phase1 or phase 2.

(b) No Effect on Non-chosen Durable Appliance Price

	Prices of Durable Appliances (NOT chosen for HAGC rebate)				
	VCR	Microwave	Electrical Fan	Sewing Machine	Rice Cooker
HAGC	1978.67	-102.45	-17.25	-35.95	24.06
	(1914)	(156)	(90)	(25)	(33)
Year FE	Yes	Yes	Yes	Yes	Yes
Household FE	Yes	Yes	Yes	Yes	Yes
Observations	456	1901	6850	3347	6633

Note: The above appliances don't belong to the HAGC rebate categories.

Table 2.4: Regression Results: Effect of Rebate on Durable Ownerships

	Dependent Variables: Durable Ownership				
	Washing Machine	Fridge	Motorcycle	Durable Index 1	Durable Index 2
Explanatory Variable	(1)	(2)	(3)	(4)	(5)
HAGC	0.057**	0.081***	0.131***	0.261***	0.132***
	(0.025)	(0.030)	(0.031)	(0.057)	(0.043)
Household FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Observations	9205	9201	9196	9244	9244

Note: All standard errors are clustered at the household level and are reported in parentheses. Post = 1 for observations from 2009 and 2011. Durable Index 1 is the sum of durable ownerships of washing machine, fridge and motorcycle. Durable Index 2 is the sum of durable ownerships of washing machine and fridge. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.5: Effect of Appliance Rebate on Home Production - OLS

Dependent Variables: Home Hours				
	Wife Home		Husband Home	
Explanatory Variable	(1)	(2)	(3)	(4)
HAGC	-2.868***	-3.141***	-1.588***	-1.366***
	(0.679)	(0.686)	(0.373)	(0.378)
Age		-0.085***		-0.030**
		(0.029)		(0.016)
Some Middle School		-0.365		-0.522
		(0.439)		(0.348)
High School Equiv.		-2.087***		0.248
		(0.604)		(0.421)
Some College		-4.717***		0.976*
		(0.959)		(0.566)
Household Income		0.405**		0.554***
		(0.222)		(0.134)
Year FE	Yes	Yes	Yes	Yes
Observations	8345	8290	8345	8290

Note: All standard errors are clustered at the household level and are reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.6: Effect of Appliance Rebate on Market Work - OLS

Dependent Variables: Market Hours				
	Wife Market		Husband Market	
Explanatory Variable	(1)	(2)	(3)	(4)
HAGC	3.520***	5.408***	2.697***	2.746***
	(0.941)	(0.930)	(0.750)	(0.750)
Age		-0.426***		-0.141***
		(0.040)		(0.033)
Some Middle School		-1.078*		-0.162
		(0.987)		(0.685)
High School Equiv.		2.625***		1.815**
		(0.604)		(0.812)
Some College		11.479***		-2.293***
		(1.086)		(0.841)
Household Income		2.518***		3.345***
		(0.320)		(0.293)
Year FE	Yes	Yes	Yes	Yes
Observations	8345	8290	8345	8290

Note: All standard errors are clustered at the household level and are reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.7: Effect of Home Appliance Ownership on Female LFP – Probit

Dependent Variables: Female LFP		
Explanatory Variable	(1)	(2)
HAGC	0.160***	0.204***
	(0.063)	(0.064)
Age		-0.027***
		(0.002)
Some Middle School		-0.256***
		(0.039)
High School Equiv.		-0.291***
		(0.053)
Some College		0.866***
		(0.105)
Household Income		0.052***
		(0.019)
Year FE	Yes	Yes
Observations	8345	8290

Note: All standard errors are clustered at the household level and are reported in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

2.8 Appendix A: Additional Figures and Tables

Table 2.8: Effect of Rebate on Wife's and Husband's Home Production Time

	Households by Rebate		
Variable	Control (1)	Treat (2)	Difference Treat-Control (3)
Wife's Home Hours (pre)	22.17	21.31	-0.86
Wife's Home Hours (post)	27.13	23.57	-5.56
Change in Mean Hours	4.96	2.26	-2.70
Husband's Home Hours (pre)	6.01	4.42	-1.59
Husband's Home Hours (post)	7.50	4.27	-3.23
Change in Mean Hours	1.49	-0.15	-1.64

Table 2.9: Effect of Rebate on Wife's and Husband's Market Work Time

	Households by Rebate		
Variable	Control (1)	Treat (2)	Difference Treat-Control (3)
Wife's Market Hours (pre)	22.90	17.84	-5.06
Wife's Market Hours (post)	25.94	26.23	0.29
Change in Mean Hours	3.04	8.39	5.35
Husband's Market Hours (pre)	38.27	29.72	-0.88
Husband's Market Hours (post)	44.44	40.21	-1.69
Change in Mean Hours	6.17	10.49	4.32

2.9 Appendix B: Instrumental Variables Analysis

Using a instrumental variables framework, we would like to estimate the causal effect of durable adoption on female labor force participation (LFP). A candidate for an instrument would be a variable that is i) strongly correlated with ownership and ii) only affects hours through ownership. The DID specification shows support for i) and although it is not possible to directly test ii), arguably, one would not expect eligibility for the rebate to affect hours directly. An example may be if money saved by the rebate leads to reduction in work hours due to a wealth effect. However, it is doubtful whether the one-time savings would be sufficient to generate this type of wealth effect. Assuming the identification assumptions hold, we can use the rebate as instrument for ownership and run the following two-stage regression:

$$Pr(work = 1) = \text{Fixed effects} + X'_{it}\beta'' + \delta''(d_t \times Treat_i) + \tau\hat{k}_i + \varepsilon_{it} \tag{2.11}$$

Again, our main interest is in parameter τ, which explains the effect of household appliances on the predicted probability of female LFP for married women. We test the effect on three appliances separately as well as the appliance index.

Table 2.10: The Effect of Durable Appliance Ownership on Home Production - IV Regression

Dependent Variables: Home Hours				
	Wife Home		Husband Home	
Explanatory Variable	(1)	(2)	(3)	(4)
Durable Ownership	-7.067**	-7.308*	3.178	3.036
	(3.729)	(6.024)	(2.301)	(2.438)
Age		0.049		0.270
		(0.091)		(0.266)
Some Middle School		-0.190		-0.367
		(0.912)		(0.613)
High School Equiv.		-0.044		-0.813
		(1.444)		(0.966)
Some College		-1.632		-1.506
		(2.069)		(1.677)
Household Income		0.559		0.012
		(0.431)		(0.226)
Household FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	6459	6411	6459	6411

Note: All standard errors are clustered at the household level and are reported in parentheses. Post = 1 for observations from 2009 and 2011. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.11: The Effect of Durable Appliance Ownership on Market Work - IV Regression

Dependent Variables: Market Hours				
	Wife Market		Husband Market	
Explanatory Variable	(1)	(2)	(3)	(4)
Durable Ownership	19.490***	20.557***	7.642*	7.030
	(6.012)	(6.438)	(4.550)	(4.809)
Age		0.122		-0.156
		(0.144)		(0.320)
Some Middle School		0.647		1.802
		(1.601)		(1.460)
High School Equiv.		-0.515		1.502
		(2.468)		(1.706)
Some College		6.678***		-3.458
		(2.804)		(2.249)
Household Income		0.314		1.118**
		(0.672)		(0.560)
Household FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	6459	6411	6459	6411

Note: All standard errors are clustered at the household level and are reported in parentheses. Post = 1 for observations from 2009 and 2011. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 2.12: Effect of Home Appliance Ownership on Female LFP –IV Probit

	Dependent Variables: Female LFP			
	Washing Machine	Fridge	Motorcycle	Durable Index
Explanatory Variable	(1)	(2)	(3)	(4)
Post × Treat	1.879***	1.387***	1.251***	0.551***
	(0.324)	(0.322)	(0.308)	(0.143)
Age	-0.008	-0.196***	-0.016***	-0.017***
	(0.006)	(0.003)	(0.004)	(0.004)
Some Middle School	-0.232***	-0.273***	-0.257***	-0.292***
	(0.040)	(0.035)	(0.037)	(0.035)
High School Equiv.	-0.501***	-0.592***	-0.225***	-0.458***
	(0.045)	(0.062)	(0.058)	(0.058)
Some College	0.257	0.329*	0.927***	0.606***
	(0.191)	(0.180)	(0.098)	(0.128)
Household Income	-0.122***	-0.112***	-0.022	-0.092**
	(0.038)	(0.045)	(0.028)	(0.043)
Household FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	8274	8272	8267	8290

Note: All standard errors are clustered at the household level and are reported in parentheses. Post = 1 for observations from 2009 and 2011. Durable Index is the sum of durable ownerships of washing machine, fridge and motorcycle. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

2.10 Appendix C: Model Details

The household utility maximization problem gives the following optimality conditions with respect to h_i, n_i and k, for $i \in \{H, W\}$:

$$
\begin{cases}
h_i: & \dfrac{\partial U}{\partial c}\dfrac{\partial c}{\partial x^h}\dfrac{\partial x^h}{\partial h_i} = \dfrac{\partial U}{\partial l_i} \\
n_i: & \dfrac{\partial U}{\partial c}\dfrac{\partial c}{\partial x^m} w_i = \dfrac{\partial U}{\partial l_i} \\
k: & \dfrac{\partial U}{\partial c}\dfrac{\partial c}{\partial x^m} p = \dfrac{\partial U}{\partial c}\dfrac{\partial c}{\partial x^h}\dfrac{\partial x^h}{\partial k}
\end{cases}
$$

These imply the following:

$$\frac{\partial c}{\partial x^h}\frac{\partial x^h}{\partial h_i} = w_i \frac{\partial c}{\partial x^m} \quad i \in \{H, W\} \tag{2.1}$$

$$\frac{\partial c}{\partial x^h}\frac{\partial x^h}{\partial k} = p \frac{\partial c}{\partial x^m} \tag{2.2}$$

Combining equation (2.1) and (2.2), we obtain:

$$\frac{\partial x^h}{\partial k} \Big/ \frac{\partial x^h}{\partial h_i} = \frac{p}{w_i} \quad i \in \{H, W\} \tag{2.3}$$

Evaluating (2.1) for both household members, we have:

$$\frac{\partial x^h}{\partial h_H} \Big/ \frac{\partial x^h}{\partial h_W} = \frac{w_H}{w_W} \tag{2.4}$$

These conditions state that the marginal rate of technical substitution between any two home production inputs is equal to the ratio of the input prices.

To further illustrate the implications of this theory for our main research question, we study the comparative statics of the model when the appliance price changes. We assume that there is a reduction in p, while other exogenous variables, such as wages, are fixed.

With the nested CES production functional form, equation (2.3) and (2.4) can be written as follows (where we evaluate (2.3) for $i = H$):

$$\left(\frac{k}{h_H}\right)^{\rho-1} = \frac{p}{w_H} \tag{2.5}$$

$$\left[\left(\frac{k}{h_H}\right)^{\rho} + 1\right]^{\frac{\sigma}{\rho}-1} \left(\frac{h_H}{h_W}\right)^{\sigma-1} = \frac{w_H}{w_W} \tag{2.6}$$

Log-linearizing the expressions (3.7) and (3.8) yields:

$$(\rho-1)\ln k - (\rho-1)\ln h_h \simeq \ln p - \ln w_h$$

$$\ln w_h - \ln w_w \simeq \frac{\sigma-\rho}{\rho}(\frac{k}{h_h})^\rho + (\sigma-1)\ln h_h - (\sigma-1)\ln h_w$$

After total differentiating the above two expressions and denoting the percentage change of variable x by g_x, we obtain, after some algebra,

$$g_p - g_{w_h} = (1-\rho)(g_{h_h} - g_k) \tag{2.7}$$

$$g_{h_h} - g_{h_w} = \frac{1}{1-\sigma}(\sigma-\rho)(\frac{k}{h_h})^\rho(g_k - g_{h_h}) \tag{2.8}$$

Since $g_{w_h} = 0$, equation (2.7) implies:

$$g_k - g_{h_h} = -\frac{g_p}{1-\rho} \tag{2.9}$$

Then equation (2.8) gives:

$$g_{h_h} - g_{h_w} = -\frac{(\sigma-\rho)g_p}{(1-\rho)(1-\sigma)}(\frac{k}{h_h})^\rho \tag{2.10}$$

and using equation (3.7) we get:

$$g_{h_h} - g_{h_w} = -\frac{(\sigma-\rho)g_p}{(1-\rho)(1-\sigma)}(\frac{p}{w_h})^{\frac{\rho}{1-\rho}} \tag{2.11}$$

These equations are important since they provide a simple way of using our model to understand how changes in the durable appliance ownership affect the changes (in percentage terms) of home production hours of husband and wife separately. Since $g_p < 0$ and $\rho < 1$, equation (2.10) implies $g_{h_H} < g_k$. If $\sigma > \rho$, equation (2.11) implies $g_{h_W} < g_{h_H}$. Thus when household capital is a closer substitute for the wife's labor relatively to the husband's labor, the percentage change in the wife's home work induced by a fall in the appliance price is smaller than the percentage change in the husband's home work. In particular (2.11) implies that the saving in home work time generated by an investment in household capital (if any) is stronger for the wife when her labor is a relatively closer substitute to household capital.

Since the total time constraint for a person is bounded to be one, any reduction of home production time due to durable adoption would lead to an increase in labor supply in the market or leisure time. Thus the model allows for a differential response of home work and market work across different household members.

Chapter 3

Home Production and China's Hidden Consumption

3.1 Introduction

China has experienced record growth in recent years, but its economy suffers from a number of imbalances, such as the excessive reliance on a limited supply of cheap labor (Das and N'Diaye 2013) and on exports (Kuo and N'Diaye 2009). One important concern is that China's private consumption as a share of GDP is too low, having reached 37% in 2008 after a steady decline from the 55% figure of the 1980s (Kuo and N'Diaye 2010). Different explanations of this fact have been proposed, each implying different policy recommendations on how to rebalance the Chinese economy[1]. However most of these analyses fail to distinguish between consumption and expenditure, a distinction that has been highlighted by recent developments in consumption theory and related empirical findings from US data[2]. Standard expenditure-based measurement of households consumption accounts only for market-produced goods while home-produced goods that are used to satisfy consumption are not accounted for. In this paper I uncover this hidden consumption within Chinese households. By showing that the value of home output is potentially large, I provide an explanation of why China's consumption share of GDP as reported in standard statistics is low.

Figure 3.1 shows some suggestive evidence that the home production channel is

[1] See for example Kuo and N'Diaye 2010, Aziz and Cui, Blanchard and Giavazzi (2005)

[2] See for example Aguiar and Hurst

potentially important in explaining the dynamics of aggregate consumption in China. I plot the growth rate of aggregate household consumption expenditure (and GDP) and the average ratio of hours spent in home production to market work hours in my dataset, over the years 2004-2009. The ratio of home work to market work falls from nearly 50% to less than 35%. At the same time, the growth rate of consumption has increased from around 6% to almost 10%. Therefore as Chinese households have reallocated more and more hours from home production to market work, the growth rate of consumption has increased. Exploring the connection between time allocation and consumption suggested by this stylized fact is the main contribution of this paper.

First, I provide evidence that home production is more important in China than in more developed countries that typically have a higher measured consumption share of GDP. This implies that the actual consumption share is underestimated by a larger margin for countries like China than for more developed countries. Previous contributions suggest that during the process of economic development time spent in household production falls[3]. Instead of studying the evolution of home production over time for a single economy, here I focus on how home production varies across different stages of economic development by carrying out a comparative study of time allocation between China and the U.S. in the last decade. The results offer a very clear picture. Between 2004 and 2009 household time allocation in the U.S. has been essentially constant with a relatively low share of household time allocated to home production. Over the same years China has experienced rapid economic growth. As the Chinese market economy expands and market institutions become stronger, time spent in home production in China has been falling considerably and tending towards the U.S. levels. However, despite the converging pattern, the time allocation of Chinese household still displays features that are typical of a developing country. First, retired individuals are very active in home production: in China a retired individual works at home 5 hours per week more than an American retired individual. Second, there is a large and growing gender gap in home production time use: the gender gap is around 5 hours per week in the U.S. and around 10 hours per week in China.

The second contribution of this paper is to structurally estimate the value of China's non-market consumption. I build a partial equilibrium model with home production technology and household preferences over time allocation. My model attempts to

[3]Ramey (2008) shows that time spent in home production by American women fell by around 18 hours from 1900 to 2005.

incorporate three stylized features of China's home production shown by the data: [4] (1) active participation of retired individuals in home production, (2) distinctive effects of individual characteristics such as gender on time allocation, (3) a general trend in home production hours. More specifically, I allow some members of the household not to participate in the labor market, while exploiting intra-household relations to link their behavior to observables. I use a flexible specification of the degree of substitutability between working at home and working in the market in the utility function. While I assume there is no joint use of time for work at home and leisure, I allow each individual to put different disutility weights on market work and home work. This is important since in order to consistently estimate the value of home production it is necessary to separate technology from preferences over time use. I include electrical appliances as proxy for general household productivity.

The main theoretical result is that the marginal product of home work corrected by the ratio of disutility from two types of work (market over non-market) equals the real wage at the individual level and across household members. These conditions provide the estimating equations from which parameters of the home production function are identified. I adopt a non-linear least squares estimation strategy and fit the model to Chinese household survey data. The empirical results illustrate a number of interesting points. The effective home work hours of different household members are not perfect substitutes in production, thus confirming that complementarities and joint rents are important. Additionally, individual characteristics affect productivity: older individuals and women have higher marginal productivity at home work. Estimates of the preference side for the model show that people do care about how their time is allocated between home and market sector with a relative preference for formal work over home work for female and less educated individual. Finally, I estimate the value of home output and the share of non-market consumption to measured GDP to be around 40% in 2009. This estimate is large but not unreasonable, as estimates of the value of household services for the US, developed between the 1930s and the 1960s, were around one third of measured gross national product (Hawrylyshyn (1976)).

This paper makes three contributions to the literature. There is a large and growing literature of empirical studies on the economics of Chinese households, but it focuses mainly on issues such as savings and migration. There is no previous study of time allocation

[4] I also estimate the value of non-market consumption by two methods often employed to measure home production in a national accounting framework. I add them as robustness check included in appendix B. Key methodologies and findings are surveyed in Hawrylyshyn (1976). To my knowledge this literature does not include any empirical comparative study between developing and developed countries.

in Chinese households as I am aware of. This paper fills in the gap by exploiting time use information from a unique household survey data set. By extracting a panel data set that spans three waves with rich demographic and socio-economic information, it is possible to make a comprehensive analysis of time use across households and over time.

The second contribution of this work is to shed light on an important macroeconomic issue for the Chinese economy. Many studies have argued that China's private consumption is exceptionally low [5]. Two main explanations for this fact have been put forward. Studies such as Blanchard and Giavazzi (2005), Kujis (2005), and Modigliani and Cao (2004) argue that low consumption is the result of a high saving rate induced by precautionary motives. An alternative explanation (see for example Aziz and Cui) attributes low consumption to an exceptionally low share of labor income. While the framework I adopt is different from these studies, as I distinguish between consumption and expenditure, the evidence and conclusion I provide are consistent with both explanations: both low income and precautionary savings intuitively lead not only to a decline in total consumption, but also to an increase in nonmarket consumption relative to market consumption.[6]

Finally this paper contributes to the literatures on the theory of home production and economic development. The theory of home production has been used to study many different issues, such as long run trends in time use, lifecycle patterns of expenditures and labor supply and the allocation of time over the business cycle, as surveyed by Aguiar et al. (2012). The relation between home production and economic development has not been a major topic in this literature yet, with the exception of Parente et al. (2000). Parente et al. (2000) introduce home production into the neoclassical growth model and compare economies with different levels of economic development. They find that less developed economies have lower hours worked in the market and higher home production hours. The predictions of this model have not been tested systematically, although a cross-country study would be feasible given the current availability of time use data. My comparative study of China and US is perhaps the first piece of evidence in support of this theory.

The rest of the paper is organized as follows. In Section 3.2 I briefly describe the dataset and present relevant summary statistics. In Section 3.3 I show four stylized facts through a comparative study on time allocation patterns between China and the U.S. over the decade. Section 3.4 offers a theoretical model of home production with model

[5]for example Kuo and N'Diaye 2010

[6]See the Conclusion section for detailed discussion on this point.

specification. In Section 3.5, I use the estimates from the structural model to quantify the potential value of underlying household consumption. Section 3.6 offers some concluding remarks and policy implications.

3.2 Data Description

The analysis of time use in China uses the 1997-2009 *China Health and Nutrition Survey* (CHNS). It is the only source of time use data that is available to the public. The survey adopts a multistage, random cluster process to draw samples of approximately 15300 observations at individual level and 4337 observations at household level with around 55% rural population. Table 3.1 gives a detailed summary statistics of the sample. [7] Observations are across nine provinces[8] that vary substantially in geography, economic development, and public resources. Table 3.2 shows summary statistics at provincial level. The survey includes a time use section (e.g. child care, elderly care, other key home activities) both in and out of formal market as well as information on labor supply, work intensity, wages and other key socio-economic variables. A complete household roster is included which allows us to link individual household members within the same household and obtain intra-household information.

To control for individual heterogeneity, I further extract a panel data that contains three waves: 2004, 2006, 2009.[9] This panel data includes 14287 individuals and 4145 households who have been reporting in the survey at least for two waves, and also whose information of key variables such as time use are not missing. The sample used in the empirical analysis is the newly contructed three-wave panel data.

In this paper, time use at home production is defined as hours per week spent on child care, cleaning, cooking, doing grocery, and doing laundry. Time spent in the market is defined as weekly working hours spent on primary occupation. Finally leisure includes weekly hours spent on physical activities (such as martial arts, gymnastics, swimming, track & field and etc.) and sedentary activity (such as watching tv and video, reading, surfing on the internet and so on.) Additionally, annual income is calculated as annual salary in the previous year plus the total value of all bonuses for the previous entire year. I use the label

[7] The educational attainment is measured as an education index, and the average value of 20.13 roughly represents 1 year of lower middle school.

[8] Guangxi, Guizhou, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Liaoning, Shandong.

[9] Due to low data quality of key variables, observations from wave 1997 and wave 2000 are dropped.

"Older female" for women who are at least 55 years old and "Older male" for men who are at least 60 years old.[10] Table 3.3 summarizes the amount of time households spend in home production from two perspectives: (1) by looking at the individual level while distinguishing among men vs. women and young vs. elderly people, (2) by linking individual observations within the same household and looking at the household level.

The analysis of time use in the U.S. uses *The American Time Use Survey* (ATUS). It is a multi-year survey from 2003 to 2012, and its data file can be linked to data files from the *Current Population Survey* (CPS). It provides nationally representative data on the full range of nonmarket activities, from childcare to excercising. Demographic information such as sex, age, educational attainment, and income are also available. Table 3.4 gives a summary of the ATUS sample. It contains about 112000 observations at the individual level. To match the time coverage of CHNS and make it comparable to CHNS, I use only three waves (2004, 2006, 2009) in the empirical analysis. Definitions for key variables are similar to the ones in CHNS,[11] and Table 3.5 provides descriptive statistics of time spent in home production for men vs. women and young vs. elderly people.

3.3 Time Use in China and in the U.S.

3.3.1 A Converging Pattern in Time Allocation between China and U.S.

Figure 3.2 shows the general trend of average hours per week people spend in working on the job, doing home work and enjoying leisure for the survey years 2004, 2006 and 2009 for both China and the US.

The average hours per week spent in doing home work for Chinese individuals drop significantly from 18 hours in 2004 to 13 hours in 2009, approaching the overall level of American individual's average home working hours . Over this time period, the average working hours per week in China only slightly increase from 38 to 40 hours, indicating that only a small proportion of time reduction from home work goes to market work in China. There is a steady increase in the amount of hours spent in leisure during the same time

[10] The way I define older female and older male is consistent with the retirement age in China, 55 for women and 60 for men.

[11] The only inconsistency in defining time use is for leisure. Because of cultural difference, people from both countries may have completely different lifestyles in how to enjoy their leisure: such as martial arts or Taijiquan is the main activity for Chinese individuals (especially seniors) while Americans spend fair amount of time in hiking or playing hockey, etc.

range .

In general, Chinese people spend more time at home work compared to American people, but less at leisure. However, this difference is becoming less striking over the years due to the economic growth in China. One explanation is that increases in the real wage in China have both income and substitution effects, providing incentives for many individuals to substitute leisure and market activity for home production. Secondly, the market for services suffers from a number of imperfections in developing countries and, as it is well known, is especially underdeveloped in China. However, this situation is rapidly changing. As the Chinese market economy expands and market institutions become stronger, the imperfections in the service sector are disappearing. These two factors may lead to a further reduction of time allocated in the home production by Chinese households, resulting in a converging pattern between US and China.

3.3.2 The Key Role of Retired Individuals in China

It is useful to look how home production varies with retirement status. Figure 3.3 shows how home production hours have changed for retired vs. non-retired individuals from 2004 to 2009.

For both countries, a retired individual on average spends more time on housework than a non-retired individual. The gap of home production between retired and non-retired appears to be larger in China than in US.

One reason why the retired gap is large in China is that the retirement age in China is relatively low compared to more developed countries: the Chinese statutory retirement age for blue-collar women is 55 and for blue-collar men is 60. The combination of a low statutory retirement age and increased longevity has resulted in a low opportunity cost of time for individuals in their 50s and 60s. A complementary explanation of the different participation level of old people in home production is that there is a stronger pattern of intergenerational transfers in China. Traditional family-based informal mechanisms of support for the elderly give rise to an upward transfer within households in China, from younger couple to old parents [12]. While elders rely on adult children for support, they also in turn provide their children with services [13]. This suggests that there might be interactions in the allocation of time among family members. An individual's home production time can

[12] see for example Cai et al. 2006

[13] Lee and Xiao 1998.

be affected by the presence of his or her old parents in the household. [14] Previous works on home production have typically ignored this issue and estimated only individual models of time allocation. The home production model I will discuss below allows interactions between young adults and retired relatives.

While the role of retired individuals in home production in Chinese household is still very important, this situation is rapidly changing. Given the expected increase in the elderly share of China's population, it is generally acknowledged that the current pension fund system is not sustainable[15]. As the Chinese population ages, increases in the statutory retirement age will soon be put into practice. With the new policy, we would expect home production hours to decline more rapidly for old people, especially for old women. More home work has to be outsourced into the market, and these changes will create consumer demand for a wide variety of household services.

Finally it is interesting to note that in the US the gap in home production between young and old is stable or shrinking, but it is widening in China. Even though average home production in China has dropped in recent years, the speed of this change has been very different for the old and the young. Young Chinese are "catching up" with young Americans at a very fast rate, especially after 2006. On the other hand, the decline in home production hours of old Chinese has proceeded at a moderate rate. The next figure will shed more light on the cause of the relatively sluggish adjustment in home production hours of Chinese elderly people.

3.3.3 A Large and Growing Gender Gap among Elderly People in China

If we analyze the home production hours of elderly people by gender, the facts are more provoking as shown by Figure 3.4. Old females in both US and China on average do more home work than old males [16]. This gender gap in home work can be attributed to culture (the different social roles that males and females play in the society) as well as to the existence of a gender gap in wages. If women face lower wages in the market, they may have incentive to allocate relatively more time to home work [17].

[14] For example, it is possible that living with parents in China significantly reduces the burden of home production on the young adult individual, increasing his or her labor supply. This hypothesis is supported by the recent study of Maurer-Fazio et al. (2011), who find that coresidency with older adults increases prime-aged women's labor force participation rates in urban China.

[15] World Bank (1997)

[16] Same pattern also shows up for working-age males and females

[17] The effect of gender difference is also taken into account in the home production model described below.

A very striking fact is that despite a decreasing trend of average home production hours for old people in China, the home production hours for old women have not changed much from 2004 to 2009. Thus the drop in home production of old males is the main determinant of the overall decreasing time spent on housework by elderly people. As a result, there is an increasing gender gap in home work among older individuals, with important implications in terms of equality and welfare.

3.3.4 Broad Reduction in Time Allocation across Home Production Categories

Figure 3.5 shows how time use at home is allocated to different categories of home production. Panel (a) plots home production hours averaged across individuals and year in the period 2004-2009 by category for both US and China. Panel (b) shows how home production hours of Chinese individuals have changed from 2004 to 2009 in different categories . Chinese households spend more time than their American counterparts on all categories of household production except house cleaning [18]. Individuals in China and the U.S. spend almost equal time on childcare [19], but the Chinese spend much more on laundry, grocery and cooking activities - with Chinese production hours for grocery and cooking roughly double the U.S. level. Cultural and economic differences may offer an explanation. For instance, lower relative prices of market substitutes of home production or better home production technologies could lead to the observed patterns. From 2004 to 2009, however, China experienced broad reduction in time allocation across home production categories. This is also consistent with the recent service sector development in China (dining service growth, etc...).

[18] Notice that the average American household size is 3 while the average Chinese household size is around 2. This may explain why Americans spend more time in house cleaning at the individual level.

[19] The American individuals childcare time may be overstated for two reasons. Firstly, childcare in CHNS dataset is defined as weekly hours spending on taking care of household children that are below 6 years old. However, due to survey data constraints, for the ATUS data I can only get the weekly hours spending on taking care for own household children under 13 years old (while the youngest child is below 6 years old). Secondly, the average number of children for a US household is around 2 while for Chinese households is only 1.

3.3.5 Home Production in China and US: Individual Characteristics and Time Trend

Table 6 summarizes how some key variables are related to home production in the U.S. and China. The regression results use CHNS[20] and the ATUS survey information at the individual level and are consistent with the graphical results above.

The left hand side variable is home production hours per week as defined earlier. The regression results show similar pattern for both dataset but differ in magnitude. The effect of age on home production time for both countries follows a reversed U-shape pattern as shown in Figure 3.6.

For both countries, home production peaks at around 40 years old on average. Before 40 years old there is a positive relation between age and home production, while after 40 years the relation turns negative. The shape of the age profile however is different between US and China: as an individual becomes older, the drop in home hours in China is much slower than the drop in US. Retired is a dummy for the individual's retirement status. The CHNS regression result shows that a retired individual tends to work around 6 hours more per week at home than a non-retired individual while the differential impact of retirment is around 5 hours in the ATUS data. Urban is a dummy equal to 1 if the individual belongs to urban type of household registration and equal to 0 if the individual belongs to a rural type of household registration[21]. On average, individuals from urban households in the CHNS work 1 hour less per week at home than individuals from rural households. The variable t is years since 2004. There is an overall decreasing trend of home production through time in CHNS: Chinese people on average work at home half hour less per week with each additional year from 2004 to 2009[22]. This general trend is likely to reflect some changes in the macroeconomy, such as a decline in market prices of household services. In the table I allow for a different trend for females and males. Female is a dummy variable equal to one if the individual is a woman. Male$\times$ t is an interaction term for addressing both gender and time effects. The estimation results demonstrate a significant effect of gender on the hours of housework. From 2004 to 2009, home production hours per week for male individuals decrease around 1 hour every year, while the weekly

[20]Random effect model estimates for CHNS are very similar to pooled-OLS therefore I will use pool-OLS estimators in the following discussion.

[21]For ATUS, urban represents living in metropolitan area.

[22]This can be shown from a regression with year-fixed effect and without year-gender interaction.

home production hours for female individuals only decrease 13 mins every year. Thus, the gap in home production time between women and men increases over time: women spend 11 home production hours per week more than men in 2004. However, in 2006 this number reaches roughly 12.3 hours per week, and further rises to around 14.75 hours per week in 2009[23]. Finally, earnings are negatively related to home production in both dataset: if weekly income increases by around 30 dollars, weekly home production hours in CHNS fall by around 20 mins while in ATUS only fall by 1 min.

3.4 The Structural Method

3.4.1 Methodology Overview

There have been many attempts to measure home production within a national accounting framework (for a survey see Hawrylyshyn (1976)). This literature has developed and applied a standard methodology. In order to simplify the discussion I introduce some notation that I will further develop later. Consider an individual with market wage W. Let H and f_H respectively be the hours of home production and the home marginal product of the individual. Let X_H be home production output and X_M some close substitute for home production available in the market. Let p be the market price of the good and W_X the market wage paid to labor for producing X_M. The monetary value of the individual's home production, V, is ideally given by $V = pX_H$. However, X_H is not observable (or very difficult to measure) and p may be difficult to compute as well. Thus the literature has usually proceeded by valuing the inputs to home production, namely H. There are essentially two standard methods of evaluating the productive services rendered by family members at home: (a) evaluating time inputs at the market cost, and (b) evaluating time inputs at their opportunity costs.

While the market cost and opportunity cost methods are standard in the valuation literature, however, they suffer from a number of limitations: First of all, both methods will underestimate the true value of home production if there are diminishing returns to home work. This fact has been overlooked in the accounting literature, but was pointed out in a passage of Gronau 1977 (p. 1122):

[23]The estimates of the coefficients on urban, t, and Male× t from the ATUS dataset are not significant, implying that there is no significant change in home production over time since 2004, nor a significant change in the gender gap over time.

> "the product of the average wage rate and the number of hours worked at home therefore understates the value of home production to the extent that diminishing marginal productivity prevails. This imputation does not account for the rent (i.e., the producer's surplus) accruing to a person who is self-employed in his own home".

Similarly, standard valuation methods fail to capture the value of potential complementarities among the household members' home production hours (joint rents). Here I present a third methodology—strutrual method based on the theory of home production that is more consistent with basic economic principles. Moreover, the structural approach provides a more coherent way to evaluate the contribution of non-employed individuals than the imputation methods used in opportunity cost valuation. This methodology exploits intra-household relations that link home production activities of a non-employed individual to the wage of employed individuals in the same household.

I describe a simple home production model, similar in many respects to standard models in the literature, such as Gronau (1977, 1980) and Graham and Green (1984). Gronau (1977, 1980) constructs a model for a married woman where the husband's decision is exogenous. It is a model of one individual who allocates time among market work, home production and leisure. The model assumes that home time produces a good that is a perfect substitute for a composite good that may be purchased on the market. Gronau tests his model's predictions by using data from the 1972 panel of the Michigan Study of Income Dynamics. Graham and Green (1984) extend the Gronau model to a two wage-earner household and allow home production and leisure to overlap to some degree. Their focus is on the estimation of the household consumption technology that consists of a Cobb-Douglas function and a "jointness" function. They estimate an equation for the home production time for married women using data from the Panel Study of Income Dynamics for 1976 and provide estimates for the value of home production.

The main differences of my model from previous works are the following: First, I allow some members of the household not to participate in the labor market, while exploiting intra-household relations to link their behavior to observables. This extension makes it possible to take into account the role of retired inviduals, which is very important as the data suggest. Second, I model both the home production technology and preferences over time allocations. I use a flexible specification of the degree of substitutability between working at home and working in the market in the utility function. While I assume there is no joint use of time for work at home and leisure, I allow each individual to put different disutility weights on market work and home work. While keepying other aspects of the model as simple as possible, I adopt some main simplifying assumption: First, I use a unitary model of the household, where the members acts so as to maximize household utility. Still, the main results (namely equations (3.7) and (3.8)) obtain also for more complicated models, such as intra-household bargaining where consumption allocation is Pareto-efficient. Second, I assume home production and market goods are perfect substitutes in consumption. While this may seem a restrictive assumption, the main results (again equations (3.7) and (3.8)) obtain also from a more general model where *some* market goods are perfect substitute of home production.

3.4.2 Household Model

As an illustration, I consider a household with three members: wife (w), husband (h) and an old relative that is retired (o). The model can be easily extended to include more complicated household structures and in the estimation I will allow an arbitrary number of working and non-working household members.

Household utility depends on household consumption and the time allocation of the household members:

$$U\left(C, H_w, N_w, H_h, N_h, H_o\right) \tag{3.1}$$

where C is household consumption, H_i is working time at home of household member i and N_i is formal working time for member i, and I set $N_o = 0$. I make no specific assumption on the household utility function $U(\cdot)$, beyond the intuitive requirements that $U_C \equiv \frac{dU}{dC} > 0$, $U_H^i \equiv \frac{dU}{dH_i} < 0$, $U_N^i \equiv \frac{dU}{dN_i} < 0$ and the usual conditions for existence of a maximum hold. When working at home and working in the market are perfect substitutes, only the total working time matters and this model reduces to a more standard utility function with consumption and leisure times as its arguments.

Total consumption of household services (C) can be obtained from the market or produced at home:

$$C = X_M + X_H \tag{3.2}$$

where X_M represents goods purchased in the market and X_H represents goods produced at home (measured in the same units as market-purchased goods). Clearly, here I focus on market and household products that are perfect substitutes in consumption.

Home production is described by the following technology:

$$X_H = f(H_h, H_w, H_o) \tag{3.3}$$

This production function is twice continuously differentiable with positive first derivatives and is strictly concave. For simplicity, I drop the use of market-purchased intermediate inputs in this formulation[24], but I will take electrical appliances into account in the actual estimation.

The household faces a budget constraint:

$$pX_M = W_h N_h + W_w N_w + v \tag{3.4}$$

where v is nonlabor income (including the retirement income of the elder relative) net of expenditure on other goods. W_h and W_w are hourly wages, and N_h and N_w are hours of work of the husband and wife respectively.

In addition, each household member faces a time allocation constraint:

$$L_i + H_i + N_i = T, \qquad i = h, w, o \tag{3.5}$$

where T equals total time and $N_o \equiv 0$.

The economic problem of the household is to choose an allocation of time that maximizes utility subject to the available technology, the household budget constraint and each member's time constraint:

$$\max U\left(C, H_w, N_w, H_h, N_h, H_o\right)$$
$$\text{s.t. (3.2), (3.3), (3.4), (3.5)}$$

The fact that all household members value an additional unit of household consumption the same, i.e. the term U_c appears in all the first order conditions, implies an important form of interdependence of choices within the household. Household utility max-

[24]Graham and Green include a market-purchased intermediate inputs, and they consider the possibility that the human capital of the household members may be more suited to market work than to home production.

imization implies that the ratio of the marginal disutility of home work to the marginal product of home work and the ratio of the disutility of market work to the real wage are equalized across household members:

$$\frac{U_H^i}{f_i} = \frac{U_N^j}{W_j/p} \quad i \in \{h, w, o\}, j \in \{h, w\} \tag{3.6}$$

It is also possible to rewrite these optimality conditions into two conditions:

$$W_i = p \cdot f_i \frac{U_N^i}{U_H^i} \quad i = h, w \tag{3.7}$$

$$W_j = p \cdot f_i \frac{U_N^j}{U_H^i} \quad i = o; j = h, w \tag{3.8}$$

Equation (3.7) is a straightforward extension of the standard condition equating the nominal wage to the nominal marginal product of home work for an individual. Here the marginal product is adjusted by the ratio of marginal disutilities of work times. All the previous studies have focused on estimating the home production function for individuals who participate in the labor market market and thus have a wage. Time allocation data on individuals who do not have a wage cannot be used to derive a production function if we rely only on estimating equation (3.7). I point out that it is still possible to estimate the parameters of a home production function for unemployed individuals by using equation (3.8). This first order condition equates the marginal product at home of individual $i = o$ to the wage of individual $j = h, w$ corrected by the ratio of marginal disutilities of formal working time and home working time of two individuals: $\frac{U_N^j}{U_H^i}$. Equation (3.8) exploits the fact that marginal utility of total consumption U_c is the same for all the household members.[25]

I estimate the parameters of the household production function using data from CHNS sample. I consider only households that have at least one working member, so that equations (3.7) and (3.8) can be estimated. Within each household, I drop individuals that are 18 years old or younger, as their time allocation decisions may not be correctly described by the model [26]. Instead of using the simple three-member introduced above, the estimation

[25] The same marginal utility of consumption for all the household members is actually the feature of a unitary household model. However a similar condition can be obtained also from a nonunitary household model, such as a bargaining model where consumption allocation is Pareto optimal.

[26] schooling or studying is probably a major time use for these individuals but the model does not include such activities

allows for a variable household size and thus the household is denoted by $\mathcal{H}$.

3.4.3 Estimation Strategy

At this point, it is necessary to adopt specific functional forms. First, I model the household preferences equation 3.1 as additively separable between consumption and labor with CES feature:

$$U\left(C, \{T_i\}_{i \in \mathcal{H}}\right) \tag{3.9}$$

where T_i serves as an index to represent total working time for household member i (and $\frac{dU}{dT_i} < 0 \forall i$). Each member's total working time index is set as a CES composite of formal working time (N_i) and working time at home (H_i):

$$T_i \equiv [d_i N_i^{\eta} + (1 - d_i) H_i^{\eta}]^{\frac{1}{\eta}} \tag{3.10}$$

The parameter $\eta \in (-\infty, 1] \setminus \{0\}$ measures the elasticity of substitution between home working time and formal working time. When $\eta = 1$ home working time and formal working time are perfect substitutes and the individual cares only about total working time, or equivalently leisure time. The parameter $d_i \in (0, 1)$ implies a disutility weight on formal working time: the higher is d_i the more the individual dislikes formal working time relative to home working time. Thus a larger d_i reflects a relative preference for home working time and a lower d_i reflects a relative preference for formal working time. While η is a constant parameter, I let d_i be individual-specific. Empirically, I assume that an individual's preference for home work versus market work are proxied by the following characteristics: education, age and gender. Additionally, d_i is set such that it is bounded between 0 and 1:

$$d_i = \{1 + \exp[-(\delta_1 edu_i + \delta_2 age_i + \delta_3 female_i)]\}^{-1} \tag{3.11}$$

When $\delta_1 = \delta_2 = \delta_3 = 0$, $d_i = 0.5$. A positive (negative) value of a δ coefficient implies a relative preference for home work (formal work) when the associated dummy is 1.

Second, home production function is described by a constant elasticity of substitution (CES) technology with equal weights on labor inputs:

$$X_H = A\left[\sum_{i \in \mathcal{H}} (E_i H_i)^{\theta}\right]^{\frac{1}{\theta}} \tag{3.12}$$

The parameter $\theta \in (-\infty; 1] \setminus \{0\}$ measures elasticity of substitution among inputs. When $\theta = 1$ inputs are perfect substitutes, when $\theta \to -\infty$ inputs are perfect complements. Additionally, E_i represents the individual level productivity (or human capital), whereas $E_i H_i$ are in fact the "effective" home hours of each household member i.

I assume that the individual productivity index E_i can be measured through a combination with individual $i's$ age, educational attainment and health status. [27]:

$$E_i = \exp(\beta_1 edu_i + \beta_2 age_i + \beta_3 female_i) \tag{3.13}$$

The parameters β_1, β_2, and β_3 capture the effect of each of the three elements on individual home productivity respectively.

Moreover, A is an index of household level productivity. Since my production function does not incorporate the household "capital" as an input, I include some of the electrical appliances usage in term A. Five dummy variables are considered: whether or not a household owns a washing machine (K_1), a refrigerator (K_2), a microwave (K_3), an electric rice cooker (K_4) and an electric pressure cooker (K_5). Additionally, I assume household level productivity is affected also by whether the household lives in an urban or rural setting:

$$A = \exp(\alpha_1 K_1 + \alpha_2 K_2 + \alpha_3 K_3 + \alpha_4 K_4 + \alpha_5 K_5 + \alpha_6 urban) \tag{3.14}$$

All these six variables are expected to enter positively into the production function ($\alpha_i > 0$) since the usage of electrical appliances and other services available to urban households are supposed to improve household productivity.

Finally, note that the price index p is estimated together with the other elements of the model.[28] Macroeconomic factors are likely to affect the nominal value of home output

[27] My choice of the variables that affect E_i and d_i is guided by Graham and Green's assumption that human capital is embodied capital and that an individual carries it into all activities, such as work, leisure and home production.

[28] The traditional price indexes such as GDP deflator or CPI are not ideal candidates to be used in our model. The reason is that the household decision on how to allocate time and money between home

only through p. Thus I assume that p depends in part on year-specific and province-specific factors:

$$p = \exp\left(\pi_0 + \sum_{m=1}^{8} \pi_m province_m + \pi_{t1} year06 + \pi_{t2} year09\right) \tag{3.15}$$

where $\{province_m\}$ are 8 province dummies [29] and $year06$ and $year09$ are year dummies for 2006 and 2009 [30]. The constant π_0 reflects the average price of household services over the years 2004-2006-2009 across all provinces. [31]This procedure does not involve any loss of relevant information, since I am not interested in p itself and the purpose of the estimation is to derive the monetary value of home output (pX_H), not its real value.

Following the model sepcification, the optimal conditions (3.7), (3.8) for each tpye of individual $i \in \mathcal{H}$ are given as follows:

$$W_i = pA\left[\sum_{l\in\mathcal{H}}(E_l H_l)^\theta\right]^{\frac{1}{\theta}-1} E_i^\theta H_i^{\theta-1} \frac{d_i}{1-d_i}\left(\frac{N_i}{H_i}\right)^{\eta-1} \text{ if } work_i = 1 \tag{3.16}$$

$$W_j = pA\left[\sum_{l\in\mathcal{H}}(E_l H_l)^\theta\right]^{\frac{1}{\theta}-1} E_i^\theta H_i^{\theta-1} \frac{d_j}{1-d_i}\left(\frac{N_j}{H_i}\right)^{\eta-1} \text{ if } work_i = 0 \tag{3.17}$$

where

$$work_i = \begin{cases} 1 & \text{if individual } i \text{ works} \\ 0 & \text{if individual } i \text{ does not work} \end{cases} \tag{3.18}$$

Note that j is a working individual that the estimation algorithm assigns to individual i from the same household $\mathcal{H}$, i.e. $work_j = 1, i, j \in \mathcal{H}$. Equations (3.16) and (3.17), with p, A, E_i, d_i given above, are the relations I will estimate. We can further fit these estimation

production and market good solely depends on the household member's wage relative to the price of the household services, not to the price of a larger basket of goods. However, a price index for household services cannot be found in public statistics.

[29]the omitted province is Liaoning

[30]the omitted year is 2004

[31]It is clear, however, that if we were to include a constant household productivity term α_0 in A, then π_0 would not be identified separately from it.

equations into a nonlinear specification as:

$$log(W_i) = f(\mathbf{X_i'}, \boldsymbol{\beta}) + \epsilon_i \tag{3.19}$$

where $\mathbf{X_i'}$ is a row vector of predictors for the ith of n observations. Specifically,

$$\mathbf{X_i'} = \begin{pmatrix} 1 & year06 & year09 & province1-8 & K1-5 & urban & edu & age & female \end{pmatrix} \tag{3.20}$$

And $\boldsymbol{\beta}$ is a vector of 25 regression parameters to be estimated. Specifically,

$$\boldsymbol{\beta} = \begin{pmatrix} \pi_0 & \pi_{t1} & \pi_{t2} & p1-p8 & \theta & \alpha1-\alpha6 & \beta1-\beta3 & \eta & \delta1-\delta3 \end{pmatrix} \tag{3.21}$$

f is a nonlinear function given by the log of the right-hand side of equations (3.16) and (3.17), represents the response of wages to all the predictors above. ϵ_i is a random error assumed to be normally distributed, iid with expectation 0 and constant variance. The estimation method we implement is nonlinear least square, i.e. minimizing the sum of squared residuals:

$$S(\boldsymbol{\beta}) = \sum_{i=1}^{n} \Big[log(W_i) - f(\mathbf{X_i'}, \boldsymbol{\beta})\Big]^2 \tag{3.22}$$

Because the relations are nonlinear, we obtain the solution by numerical optimization using Stata. Estimation of equation 19 requires data on the following variables: the nominal wage W_i, home production time for each individual in the same household H_i, individual characteristics such as education, age and gender and electrical appliances usage. Most importantly it requires data that links individuals within the same household. It finally left us with 4575 observations at individual level.

3.4.4 Estimation Results

Table 7 reports the non-linear least square estimation results using the CHNS dataset.[32] As shown by the figure, the empirical estimates also suggest that the nominal marginal product of home work has increased over time[33].

[32] Estimates for provinces dummies are not reported in Table 7 for simplicity, but the effect of provinces on home production will be shown in the valuation part in the next section.

[33] both year dummies are positive and significant, with $\pi_{t1} < \pi_{t2}$

Turning to the estimates for technology, the estimate of θ is highly significant and moreover, the estimated θ is significantly different from one (p-value=0.000). This result is consistent with the concern discussed in the introduction that the effective home work hours of different household members are not perfect substitues and evaluating the contribution to home production of each individual separately from the others misses important complementarities and joint rents.

As we expected, all the general household productivity parameters have positive signs. In particular, usage of microwaves (α_3) significantly improve household level productivity [34]. Living in an urban area (α_6) improves household productivity significantly. As regards individual level productivity, education (β_1) has a negative but insignificant effect. Being a senior (β_2) has a positive effect on one's productivity at home, perhaps due to experience. Moreover, being a woman increases one's marginal productivity at home (β_3) [35].

Finally estimates of the preference side of the model show that individuals do care how their working time is allocated between home work and market work as they are not perfect substitutes: the estimated elasticity of substitution (η) is significantly lower than one (p-value=0.000). Specifically for each individual, a higher education is associated with a relative preference for home work over formal work ($\delta_1 > 0$). Women significantly prefer formal work over home work ($\delta_3 > 0$), although empirical evidence shows women work more inside the house than men. Age does not seem to affect an individual's preference in a significant way (δ_2 is insignificant).

3.5 The Value of Non-Market Consumption

Given the characteristics of a household, the parameter estimates of the production function can be used to compute the nominal value of home output as:

$$V^{\text{structural}} = pX_H = pA\left[\sum_{i\in\mathcal{H}}(E_iH_i)^{\theta}\right]^{\frac{1}{\theta}} \tag{3.23}$$

The structural method requires information at both the household and individual level. pA is computed by using the estimates from the household level. Similarly, the individual

[34] Estimation results for washing machine (α_1) and refrigerator (α_2) are almost significant

[35] Gender is coded as 1 for female and 0 for male

level productivity terms, E_i is computed using the individual level estimates. In this way I obtain the nominal value of non-market consumption for every household in each year. In order to gauge the magnitude of non-market consumption, I compare its aggregate value to total income in the sample. I compute total income by summing all the individual-level income variables, including not only wages but also retirement pensions and profits among other variables. I use the ratio of the aggregate nominal value of non-market consumption value to total income as an estimator of the ratio of non-market consumption to measured GDP. I present the valuation results in Figure 3.7 and Figure 3.8.

In Figure 3.7 I plot the aggregated nominal value of non-market consumption and total income in the sample. The nominal value of home output has steadily increased from 2004 to 2009, but at the same time household income more than doubled.

In Figure 3.8 I plot the ratio of non-market consumption to income for the years 2004-2006-2009 and for each of the nine provinces as well as for the whole sample. Several interesting observations can be made. First, there is significant heterogeneity among provinces, although provinces seem to be converging to a similar level. This may be due to regional differences arising from the rate of economic growth, the development level of market institution and the depth of the urbanization process. Second, despite heterogeneous provincial evidence, there is a clear downward trend in the non-market consumption to income ratio since 2004. Despite the significant change occurred over the past decade, non-market consumption still represents a large share of economic activity in 2009, as the estimated ratio of non-market consumption to measured GDP is around 35%. This estimate is large but not unreasonable, as estimates of the value of household services for the US, developed between the 1930s and the 1960s, were around one third of measured gross national product (Hawrylyshyn (1976)).

3.6 Conclusion and Policy Implications

I explore the hypothesis that home production in China has absorbed a disproportionately high fraction of economic activity because of distortions typical of a developing country, such as market failures and low opportunity cost of time for individuals in their 50s and 60s. I provide support for this hypothesis by a comparative study of time allocation between China and US. I use data from the American Time Use Survey and the Chinese Health and Nutrition Survey between 2004 and 2009. The results offer a very clear picture.

Home production hours are significantly higher in China than in the US. While in the past decade time allocation in China has tended towards US levels, the time allocation pattern shown by Chinese data still display features that are typical of a developing country. First, retired individuals are very active in home production: in China a retired individual works at home 5 hours per week more than an American retired individual. Second, there is a large and growing gender gap in home production hours: the gender gap is around 5 hours per week in US and around 10 hours per week in China.

The second contribution of this paper is to provide an estimate of the value of non-market consumption in China. The main strategy I employ is a structural approach based on estimating the home production function. I also estimate the value of non-market consumption by two methods often employed to measure home production in a national accounting framework. In order to implement the structural approach I formulate a model of household consumption and time use that improves on existing literature by modeling preferences over market- vs. non-market work and by including non-employed household members. The main theoretical result is that the ratio of the marginal disutility of home work to the marginal product of home work and the ratio of the disutility of market work to the real wage are equalized at the individual level and across household members. These conditions provide the estimating equations from which parameters of the home production function are identified. I fit the model to Chinese data and I estimate the share of non-market consumption in GDP to be around 40% in 2009.

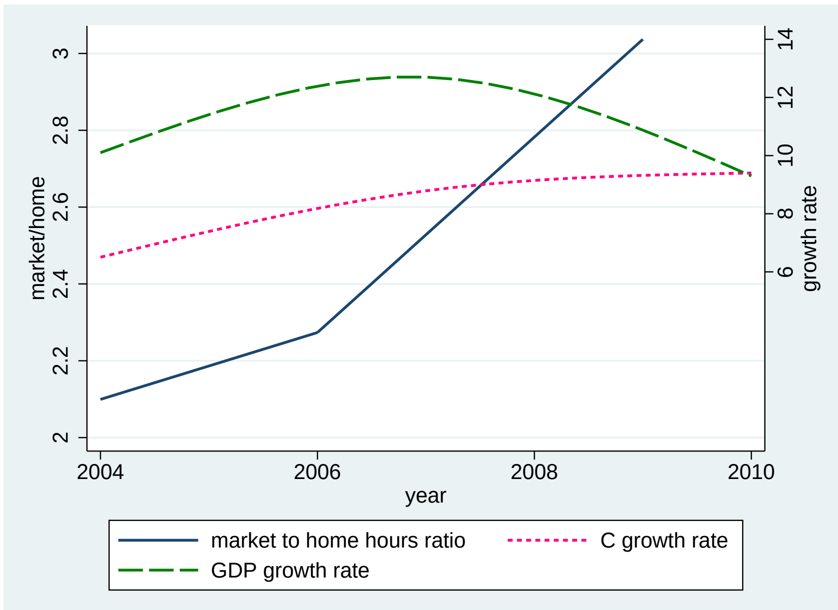
The evidence presented in this paper has several policy implications. I show that non-market consumption is quantitatively significant for the Chinese economy and analyses that neglect it would miss an important aspect of the economics of Chinese household. However, the message to the policy makers is not to dismiss the problem of the low record in the GDP share of private expenditure as non-market consumption makes up for it. Rather that rebalancing the Chinese economy towards a more private demand oriented market is also a matter of shifting consumption from the household into the market. Many gains could possibly be attained by producing the same consumption services through more market work and less home work, such as: more fairness in the intra-household allocation, economies of scale that cannot be exploited within families and positive externalities related to a more formal job environment (e.g. the fostering of a "market culture").

As highlighted in my theoretical analysis the main determinant of the excessively large share of non-market consumption in total consumption is a low wage relative to the price of market substitutes for home production (i.e. household services). This suggests that market-consumption can be raised by policies that address imperfections in the market for household services, increasing competition and lowering prices. Additionally, it may be important to address factors leading to low wages, especially for some categories, such as women. Similarly, in order to rebalance the Chinese economy towards more market-consumption it seems important to increase labor market participation rates especially for women and older but still active individuals. Finally, improving the social security and pension system may also be important. One more reason, not formally analyzed here, that why individuals rely more on home production for current consumption is that they may use market income for precautionary savings. Assume that an individual faces future random shocks to human capital, affecting productivity both in home work and market work (e.g. health shocks). The individual then saves out of current income to smooth future consumption in the event of such a shock. If we allow the individual to engage in home work, we can expect a much larger decrease in current market consumption. The reason is that since home production cannot be stored for future consumption the individual uses most of his market income for precautionary savings, relying more on home production for current consumption needs. I leave a formal analysis of this argument to future research.

A further benefit of the approach presented in this paper is to help quantifying the potential gains in private demand that could result from rebalancing the Chinese economy. Back of the envelope calculations not reported here show that, fixing the value of total consumption, if China fully converges to the US level of home work then weekly consumer demand is forecasted to increase by around 25%.

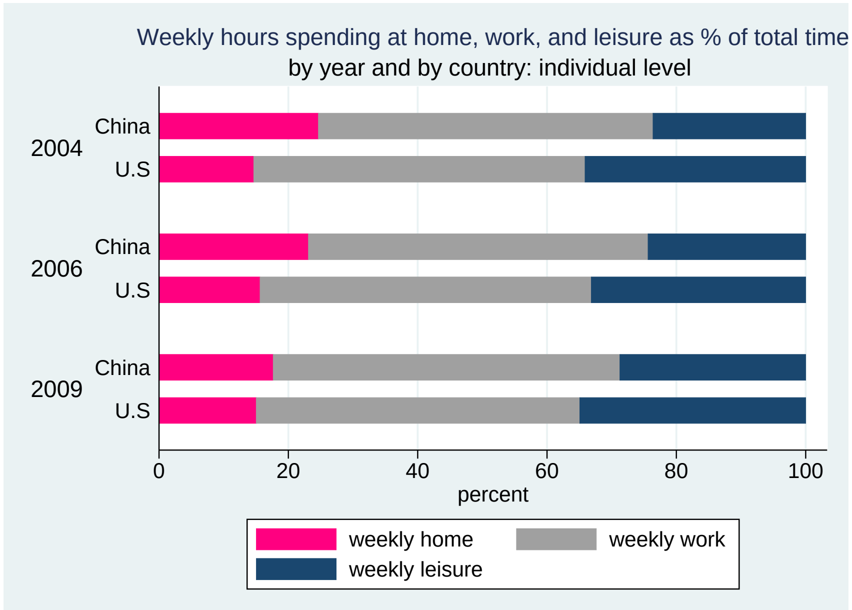
3.7 Figures and Tables

Figure 3.1: Home to Market Hours Ratio and Growth Rate of Consumption, GDP



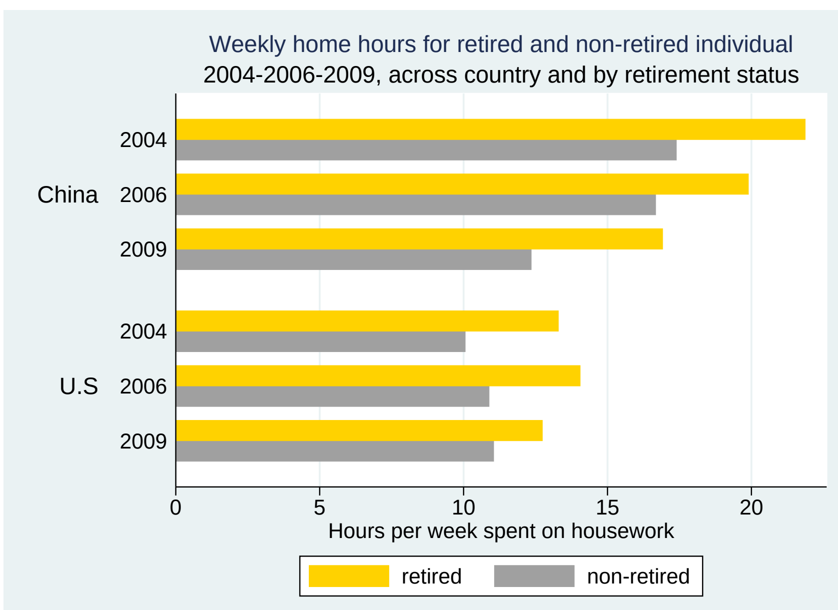
Sources: World Development Indicators, World Bank; CHNS, and author's calculation.
Note: C is defined as household final consumption expenditure

Figure 3.2: Converging Pattern in Time Allocation between China and US



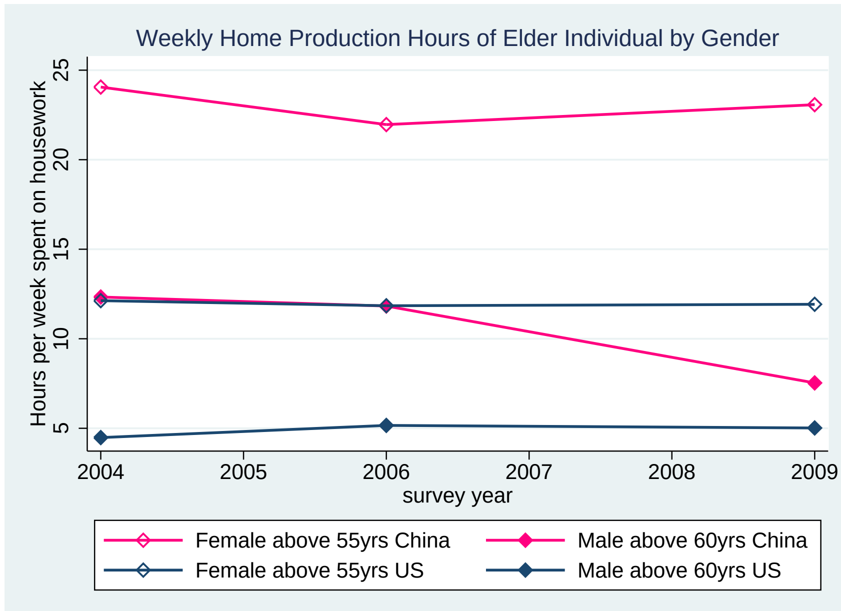
Note: Author's calculation for time use on home work, market work and leisure is given under Data Description section. Observations of time use are reported at individual level.

Figure 3.3: The Key Role of Retired Individuals in China



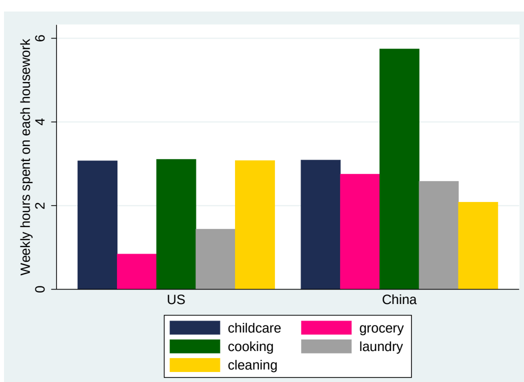
Note: Retirement status is categorized by self-report information in the CHNS and ATUS survey questionnaires.

Figure 3.4: Large and Growing Gender Gap among Elderly People in China

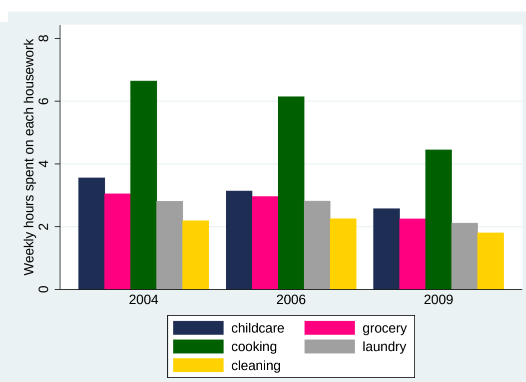


Notes: To make two groups of observations comparable, the same definition is applied to both China and the US for old female (no younger than 55 years old) and old male (no younger than 60 years old). Similar pattern is found if observations are categorized by retirement status.

Figure 3.5: Broad Reduction in Time Allocation across Home Production Categories



(a) Comparison between US and China



(b) Change of Home Production by Category for China

Figure 3.6: Age Profile for US and China

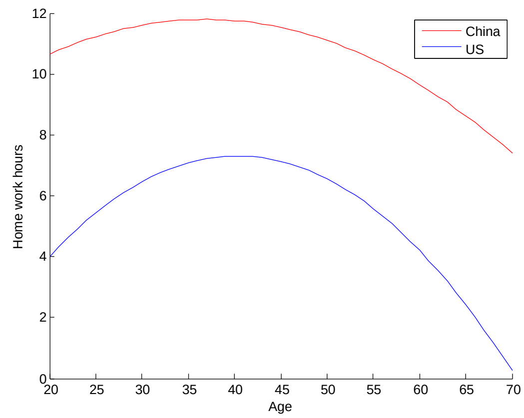
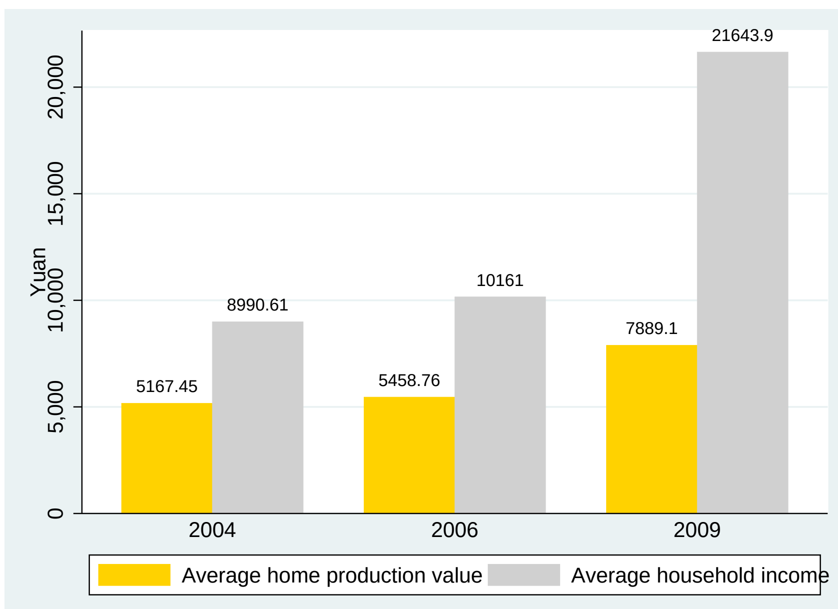
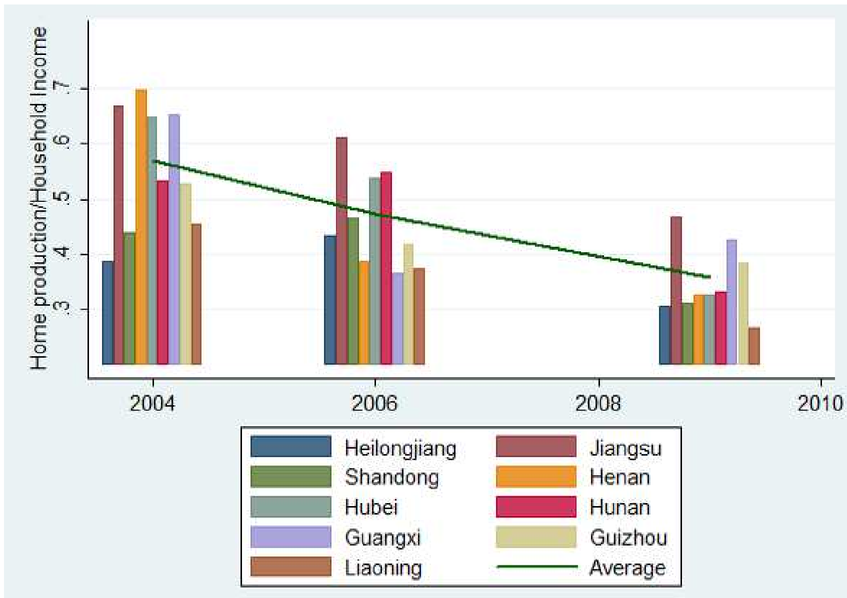


Figure 3.7: Consumption at Home and Household Income



Notes: Source: CHNS and author's calculation. Variables are reported as average across household at year 2004, 2006 and 2009.

Figure 3.8: Household Consumption as a Percentage of Income–by Province



Notes: Average represents the percentage of the total household consumption over total household income across province in each year.

Table 3.1: Descriptive Statistics - CHNS

	Obs	Mean	Std.Err.	Min	Max
A. Demographic Variables					
Age	15659	47.04	14.3314	13.2	93.13
Fraction female	15659	.53	.4993	0	1
Married	15659	.87	.3358	0	1
Education	15500	20.13	8.4494	0	36
Fraction retired	15659	.18	.3836	0	1
Household size	15659	1.94	.8841	1	7
Number of olders	15659	.46	.7105	0	3
B. Geographic Variables					
Rural	15659	.55	.4972	0	1
Urban	15659	.45	.4971	0	1
C. Time Allocation					
Work hours	12505	39.71	19.9694	1	126
Home hours	15659	15.73	17.8016	0	266
Leisure hours	14827	19.49	15.9163	0	248
D. Income					
Annual income	5110	15580.72	20973.92	480	480000
Retirement wage	2720	13726.28	11131.31	240	119988

Source: CHNS survey and author's calculation.

Table 3.2: Provincial Level Summary - CHNS

Province	Obs	Age	Female	Edu	Retired	Married	Urban	Income	Work	Home	Leisure
Liaoning	1819	53.13	.55	22.48	.30	.90	.59	15830	44.99	16.87	21.62
Heilongjiang	1579	47.91	.52	22.68	.15	.91	.45	16964	43.51	16.22	20.57
Jiangsu	2517	52.48	.55	19.30	.22	.89	.54	16196	38.83	16.49	17.69
Shandong	1472	51.17	.51	19.74	.25	.86	.54	15200	45.26	14.04	22.26
Henan	1640	48.90	.53	19.52	.12	.87	.34	13279	38.52	17.32	18.73
Hubei	1657	50.38	.53	19.65	.17	.87	.40	15200	37.42	15.84	19.60
Hunan	1269	50.49	.49	22.00	.17	.86	.50	20677	39.53	15.70	23.28
Guangxi	1806	49.29	.51	20.16	.13	.82	.35	11162	38.90	16.26	17.23
Guizhou	1900	51.15	.53	16.85	.09	.85	.28	15473	34.03	16.28	16.79
National	15696	50.68	.53	20.13	.18	.87	.45	15581	39.71	12.30	19.49

Table 3.3: Statistics on Home Production Time - CHNS

	Obs	Mean	Std.Err.	Min	Max
A. Different Age Groups					
All age cohorts	14287	15.72	16.9187	0	266.00
Young female	4961	21.88	19.0661	0	266.00
Young male	4827	7.29	10.3710	0	151.50
Older female	2975	23.03	17.0262	0	227.33
Older male	2064	10.08	12.1302	0	165.50
B. Household Level					
Individual	7648	14.11	16.6121	0	227.33
Spouse	6876	18.16	17.1378	.12	227.33
Elder mother	853	25.05	19.6719	1.17	162.75
Elder father	598	11.52	12.0115	.12	94.00
Household	4145	32.21	23.4179	0.47	248.50

Table 3.4: Descriptive Statistics - ATUS

	Obs	Mean	Std.Err.	Min	Max
A. Demographic Variables					
Age	112038	46.19	17.5814	15	85
Fraction female	112038	.57	.4957	0	1
Married	112038	.63	.4822	0	1
Education	112038	40.11	2.8996	31	46
Fraction retired	112038	.32	.4651	0	1
Household size	112038	2.83	1.5319	1	16
Number of children	25152	2.14	1.0766	1	12
B. Geographic Variables					
Rural	112038	.13	.3385	0	1
Urban	112038	.60	.4891	0	1
C. Time Allocation					
Work hours	60830	38.98	11.8532	0	99
Home hours	112038	11.24	16.4993	0	190.17
Leisure hours	112038	25.71	22.1635	0	165.32
D. Income					
Annual income	60830	42130.21	31992.78	0	149999.7

Note: Leisure is defined not exactly the same as in CHNS due to cultural reasons.

Table 3.5: Statistics on Home Production Time - ATUS

	Obs	Mean	Std.Err.	Min	Max
Different Age Groups					
All age cohorts	112038	11.24	16.4993	0	190.17
Young female	42292	17.23	20.8604	0	190.17
Young male	38236	6.06	11.0860	0	161.00
Older female	21059	11.85	13.2627	0	121.10
Older male	10451	4.75	8.1765	0	113.75

Note: Statistics are not reported at the household level (as in CHNS) because of data coverage issue.

Table 3.6: Home Production-Individual Characteristics and Time Trend

Home Hours	CHNS(OLS)	CHNS(RE)	ATUS(OLS)
Age	0.295***	0.309***	0.645***
	(0.095)	(0.093)	(0.022)
Age^2	-0.004***	-0.004***	-0.008***
	(0.0009)	(0.0009)	(0.0002)
Retired	6.350***	6.193***	5.153***
	(0.647)	(0.648)	(0.256)
Female	11.270***	11.542***	9.675***
	(0.615)	(0.608)	(0.220)
Urban	-0.973**	-0.989**	0.191
	(0.438)	(0.428)	(0.181)
t	-0.229**	-0.236	0.0444
	(0.153)	(0.154)	(0.062)
Male × t	-0.730***	-0.673***	0.113
	(0.167)	(0.163)	(0.072)
Earnings	-0.369***	-0.350***	-0.115***
	(0.084)	(0.081)	(0.028)
Constant	6.354***	5.800***	-5.694***
	(2.181)	(2.133)	(0.496)
N	14827	14827	40049

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: The coefficients reported in the first column and the second column are pooled-OLS and random effect estimators using CHNS data.

All standard errors clustered at the county level for CHNS

Education is dropped since the coeffiecient is insignificant after adding earnings as an explanatory variable.

The coefficients reported in the third column are OLS estimators with robust standard errors using ATUS data.

For ATUS, urban = 1 represents living in metropolitan area.

Table 3.7: Non-Linear Least Square Estimation Results for Home Production Model

		(1)
		logw
Price Level	π_0	0.365***
		(4.10)
	π_{t1}	0.154***
		(6.45)
	π_{t2}	0.536***
		(23.52)
Household Productivity	θ	0.940***
		(87.15)
	α_1	0.057
		(1.90)
	α_2	0.048
		(1.75)
	α_3	0.225***
		(10.14)
	α_4	0.015
		(0.48)
	α_5	0.010
		(0.48)
	α_6	0.064**
		(2.71)
Individual Productivity	β_1	-0.013
		(-1.24)
	β_2	0.006*
		(2.55)
	β_3	0.559***
		(4.30)
Preferences	η	0.861***
		(81.83)
	δ_1	0.050***
		(4.84)
	δ_2	-0.003
		(-1.06)
	δ_3	-0.861***
		(-6.87)
N	4575	

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Note: Province dummies are omitted for simplicity.

3.8 Appendix A: Derivation

The optimality conditions are obtained as follows. First I subtitute (3.2), (3.3), (3.4), (3.5) in the objective function:

$$U\left(f(H_h, H_w, H_o) + \frac{W_h}{p}N_h + \frac{W_w}{p}N_w + \frac{v}{p}, H_w, N_w, H_h, N_h, H_o\right) \tag{3.24}$$

Then I take the first derivatives with respect to N_i and H_i and set them equal to zero. For each $i = h, w$, this leads to two equations:

$$U_H^i + U_c \cdot f_i = 0 \quad i \in \{h, w, o\} \tag{3.25}$$

$$U_N^i + U_c \cdot W_i/p = 0 \quad i \in \{h, w\} \tag{3.26}$$

Then rewrite the first order conditions as:

$$\frac{U_H^i}{f_i} = -U_c \quad i \in \{h, w, o\} \tag{3.27}$$

$$\frac{U_N^i}{W_i/p} = -U_c \quad i \in \{h, w\} \tag{3.28}$$

which implies:

$$\frac{U_H^i}{f_i} = \frac{U_N^j}{W_j/p} \quad i \in \{h, w, o\}, j \in \{h, w\} \tag{3.29}$$

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