American Economic Journal: Macroeconomics 2017, 9(3): 116–146
https://doi.org/10.1257/mac.20150109

Does Home Production Drive Structural Transformation?†

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Using new home production data for the United States, we estimate a model of structural transformation with a home production sector, allowing for both non-homotheticity of preferences and differential productivity growth in each sector. We report two main findings. First, the estimation results show that home services have a lower income elasticity than market services. Second, the slowdown in home labor productivity, which started in the late 70s, is a key determinant of the rise of market services. Our counterfactual experiment shows that, without the slowdown, the share of market services would have been lower by 7.5 percent in 2010. (*JEL* D13, J24, L16)

Since the early 1990s, a number of studies have incorporated household home production in a neoclassical framework in order to explain several macroeconomic phenomena.[1] Structural transformation is one of the fields in which researchers have recently been discussing the role of home production.[2] While previous studies in this field have successfully derived rich implications by modeling home production, empirical works that assess the model's ability to explain the data have been limited. Therefore, an important question to be addressed in this literature is whether a structural transformation model with a home production sector is able to account for the actual home production data.

In this paper, we propose and estimate a model of structural transformation with a home production sector that can account for the movements of the home and

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† Go to https://doi.org/10.1257/mac.20150109 to visit the article page for additional materials and author disclosure statement(s) or to comment in the online discussion forum.

[1] These studies include issues on business cycles (Benhabib, Rogerson, and Wright 1991; Greenwood and Hercowitz 1991), life-cycle labor supply decisions (Ríos-Rull 1993), and fiscal policy (McGrattan, Rogerson, and Wright 1997), among others.

[2] The structural transformation literature started discussing home production following two seminal papers, Rogerson (2008) and Ngai and Pissarides (2008).

market sector shares in extended total consumption in the United States.[3] In order to construct the home production data for the estimation, we follow the income approach recently developed in the literature, and compute the value added of home production from its input factors and their prices.[4] We then use the estimated model to study the role of a home production sector in the process of structural transformation. In particular, we run a counterfactual experiment to quantify the effects of the slowdown in home labor productivity growth in the United States after the late 1970s, which is documented in Bridgman (2013).

Our framework is based on a multi-sector growth model in which structural transformation is generated through non-homothetic preferences and differential productivity growth across sectors, as in Buera and Kaboski (2009). We extend this model to include a home production sector operated by the household. Since the inter-temporal and the intra-temporal problems can be solved independently in this class of growth models with structural transformation, we can rewrite the latter as a static, consumption choice problem of the household, which depends on the prices of the three market goods, the implicit price of home produced services, and the extended total consumption. This last version of the model allows us to estimate the implied share equations, using the home production data together with the value-added consumption data for the market sectors.

In the estimation, we explore different household preferences specifications. In particular, we allow for *different* income elasticities of home and market services in the household consumption demand, something that has not been considered in the previous literature.[5] This is motivated by the empirical evidence documented in Eichengreen and Gupta (2013), which suggests that market services with a home counterpart could have a different income elasticity from the other services. In our results, it turns out that this feature of the model is crucial to account for the data.

We highlight two main results. First, we find that home services have a *lower* income elasticity than market services. The estimation results indicate that if the income elasticities are the same between market and home services, the model cannot generate the secular decline of the home service share from the late 1940s onward (see panel A in Figure 1). This result contrasts with previous studies in the literature, which explain the movement of market and home service shares only through differences in the rates of technological progress across sectors.[6] Our estimates suggest that the changes in technologies are not enough to account for the movement of the home and market shares observed in the data.

The second result is obtained by running a counterfactual experiment, in which we assume the growth rate differential between home labor productivity and market service labor productivity after 1978 is the same as that in the period 1947–1978. We find that in the counterfactual the share of market services in the total consumption expenditure is 0.80 in 2010, compared to 0.86 in the benchmark estimation, which

[3] We define extended total consumption as the value of market consumption plus the value added of home production.

[4] Our income approach is similar to those in Landefeld, Fraumeni, and Vojtech (2009) and Bridgman (2013).

[5] A common assumption in previous works is to assume the same income elasticity for home and market services. See, for instance, Rogerson (2008), Ngai and Petrongolo (2013), and Rendall (2015).

[6] See Ngai and Pissarides (2008) and Buera and Kaboski (2012b) for examples.

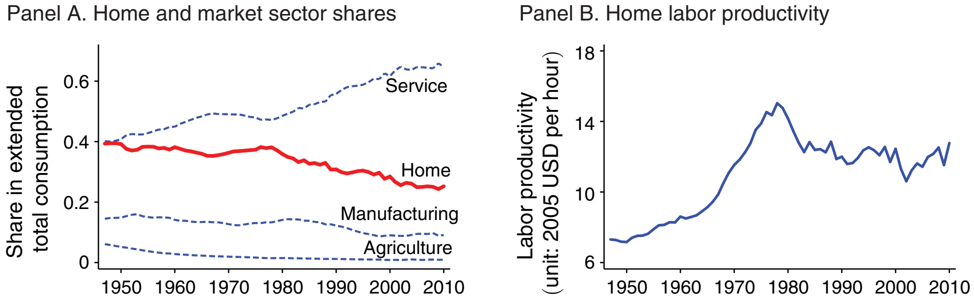

FIGURE 1. HOME AND MARKET SECTOR SHARES (PANEL A) AND HOME LABOR PRODUCTIVITY (PANEL B)

Notes: The consumption value added of the market sectors is calculated based on the data of Herrendorf, Rogerson, and Valentinyi (2013). The consumption value added of the home sector is calculated by using the income approach similar to Bridgman (2013). The home labor productivity is obtained by deflating the value added of home production with the price index for the home sector and then dividing it by hours worked at home. The details of the data used here are discussed in Section III.

represents a 7.5 percent decrease. That is, if there were no slowdown in home labor productivity, the extent of structural change would be considerably lower than the actual data indicates. This experiment therefore suggests that the home production sector can have quantitatively important implications for the structural change observed in market sectors.

Our paper relates to the literature, started by Rogerson (2008) and Ngai and Pissarides (2008), that considers home production as a key determinant in the process of structural transformation. More recent studies in this literature include Buera and Kaboski (2012a) who focus on differences in skill intensities between home and market, Buera and Kaboski (2012b) who model differences in production scale between home and market, Ngai and Petrongolo (2013) who study the rise of female labor force participation in the United States, and Rendall (2015) who analyzes the implications of the difference in the tax system for female labor force participation between the United States and Germany. As emphasized above, while these studies have derived rich implications from structural transformation models with a home production sector, they do not estimate these models using actual home production data.

There are two recent contributions that estimate a model of structural transformation *without* a home production sector using the US data. On the one hand, Buera and Kaboski (2009) estimates a three-sector model using the US data in a general equilibrium framework. Herrendorf, Rogerson, and Valentinyi (2013), on the other hand, considers a partial equilibrium setup, and estimates a three-sector model using final consumption expenditure and consumption value-added data since 1947. Our methodology is close to that of Herrendorf, Rogerson, and Valentinyi (2013). However, we consider a structural transformation model *with* a home production sector, and estimate the model using the value added of home production together with consumption value-added data for the market sectors.

Finally, our paper is also related to the literature which has developed the income approach to impute the value of nonmarket activities from input factors and their market prices. This idea goes back as far as Kendrick (1979). In recent years, researchers at the US Bureua of Economic Analysis (BEA) have further developed this approach to construct their Satellite Account for Household Production (Landefeld and McCulla 2000; Landefeld, Fraumeni, and Vojtech 2009; Bridgman et al. 2012; and Bridgman 2013). This paper's strategy to construct the home value added closely follows these works.

The remainder of the paper is as follows. Section I presents the model; Section II discusses the estimation procedure; Section III explains the data; Section IV reports the estimation results, while Section V runs the counterfactual experiment. In Section VI, we consider an extension by disaggregating the service sector. In Section VII, we discuss the implications of the model for hours worked. In Section VIII, we conclude.

I. Model

This section presents a model of structural transformation with a home production sector.

A. *Setup*

Time is discrete. There is a representative household whose objective is to maximize her utility. There are five types of goods produced in this economy: four consumption goods (agriculture, manufacturing, market services, and home services) and one investment good. The household's preferences are given by

$$u = \sum_{t=0}^{\infty} \beta^t \ln C_t,$$

where β is the subjective discount factor. The composite consumption index C_t is defined as

$$C_t = \left(\sum_{i=a,m,s} \left(\omega^i\right)^{\frac{1}{\sigma}} \left(c_t^i + \bar{c}^i\right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}, \tag{1}$$

where c_t^i denotes consumption of good $i \in \{a, m, s\}$. In (1), the parameter ω^i determines the weight on each good in the household's preferences; the parameter $\bar{c}^i$ controls non-homotheticity in preferences; and the parameter σ governs the elasticity of substitution among the three goods. Service consumption is a composite of market services, c_t^{sm}, and home produced services, c_t^{sh}, as

$$c_t^s = \left[\psi \left(c_t^{sm} \right)^{\frac{\gamma-1}{\gamma}} + (1 - \psi)\left(c_t^{sh} + \bar{c}^{sh}\right)^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}}. \tag{2}$$

In (2), the parameter γ governs the elasticity of substitution between market and home services, and ψ is the share parameter in the service aggregator. Note that we allow for a different income elasticity between market and home services through the parameter $\bar{c}^{sh}$. We provide a discussion of this parameter in Section ID and in the estimation section.

In our setup, for each period, the household is endowed with $\bar{l} = 1$ unit of labor that she splits into working time in the market, l_t^{mk}, paid at wage w_t, and working time at home, l_t^{sh}. Also, the household holds the capital stock k_t in the economy, and decides how much to rent in the market, k_t^{mk}, at rate r_t, and how much to use in home production, k_t^{sh}. Then, the household's constraints are given by

$$(3) \quad p_t^a c_t^a + p_t^m c_t^m + p_t^{sm} c_t^{sm} + k_{t+1}^{mk} - (1 - \delta) k_t^{mk} + k_{t+1}^{sh} - (1 - \delta) k_t^{sh}$$

$$= r_t k_t^{mk} + w_t l_t^{mk},$$

$$l_t^{mk} + l_t^{sh} = \bar{l},$$

where p_t^j is the price of good $j \in \{a, m, sm\}$ and δ is the depreciation rate. We normalize the price of the investment goods to be equal to one. The total amount of capital is defined as

$$k_t \equiv k_t^{mk} + k_t^{sh}.$$

The household produces home services through the following technology:

$$c_t^{sh} = A_t^{sh} (k_t^{sh})^{\alpha} (l_t^{sh})^{1-\alpha}.$$

On the market production side, there is a perfectly competitive firm in each market sector $j \in \{a, m, sm\}$, with technology

$$Y_t^j = A_t^j (K_t^j)^{\alpha} (L_t^j)^{1-\alpha}.$$

Finally, there is also a perfectly competitive firm operating in the investment good sector, with technology

$$Y_t^x = A_t^x (K_t^x)^{\alpha} (L_t^x)^{1-\alpha}.$$

B. *Household's Problem*

Next, we rewrite the previous setup by treating the home production sector as being operated by a perfectly competitive firm. This allows us to consider the home production sector as an additional market sector, which helps us to simplify the problem. Assuming perfect competition in the home sector, we can define an implicit price index for the home good as

$$(4) \qquad p_t^{sh} \equiv \frac{r_t^{\alpha} w_t^{1-\alpha}}{A_t^{sh} \alpha^{\alpha} (1 - \alpha)^{1-\alpha}}.$$

Using the above price, we can show that

$$(5) \qquad p_t^{sh} c_t^{sh} = w_t l_t^{sh} + r_t k_t^{sh}.$$

We now add up (5) to the budget constraint of the household, (3), and obtain

$$p_t^a c_t^a + p_t^m c_t^m + p_t^{sm} c_t^{sm} + p_t^{sh} c_t^{sh} + k_{t+1} - (1 - \delta) k_t = r_t k_t + w_t \bar{l}.$$

Thus, we can rewrite the household problem as

$$\text{(P1)} \qquad \max \sum_{t=0}^{\infty} \beta^t \ln C_t$$

subject to

$$C_t = \left(\sum_{i=a,m,s} (\omega^i)^{\frac{1}{\sigma}} (c_t^i + \bar{c}^i)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}},$$

$$c_t^s = \left[\psi (c_t^{sm})^{\frac{\gamma-1}{\gamma}} + (1 - \psi)(c_t^{sh} + \bar{c}^{sh})^{\frac{\gamma-1}{\gamma}} \right]^{\frac{\gamma}{\gamma-1}},$$

$$p_t^a c_t^a + p_t^m c_t^m + p_t^{sm} c_t^{sm} + p_t^{sh} c_t^{sh} + k_{t+1} - (1 - \delta) k_t = r_t k_t + w_t \bar{l}.$$

Given the definition of the implicit price for home services (4), it is straightforward to show that problem (P1) is equivalent to the original setup in Section IA.

C. *Separating Inter-temporal and Intra-temporal Problems*

As the final step toward the estimation, we show that the household's problem (P1) can be decomposed into the following two problems.[7]

(i) *Inter-temporal Problem*: The household solves:

$$\text{(P2)} \qquad \max_{\{C_t, k_{t+1}\}} \sum_{t=0}^{\infty} \beta^t \ln C_t$$

subject to

$$P_t C_t + k_{t+1} - (1 - \delta) k_t = r_t k_t + w_t \bar{l} + p_t^{sh} \bar{c}^{sh} + \sum_{i=a,m,s} p_t^i \bar{c}^i,$$

where

$$P_t \equiv \left[\sum_{i=a,m,s} \omega^i (p_t^i)^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

and

$$p_t^s \equiv \left[\psi^\gamma (p_t^{sm})^{1-\gamma} + (1 - \psi)^\gamma (p_t^{sh})^{1-\gamma} \right]^{\frac{1}{1-\gamma}}.$$

[7] See online Appendix A for details.

(ii) *Intra-temporal Problem*: The household solves:

$$\text{(P3)} \qquad \max_{c_t^a, c_t^m, c_t^{sm}, c_t^{sh}} \left(\sum_{i=a,m,s} \left(\omega^i\right)^{\frac{1}{\sigma}} \left(c_t^i + \bar{c}^i\right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

subject to

$$c_t^s = \left[\psi \left(c_t^{sm}\right)^{\frac{\gamma-1}{\gamma}} + (1-\psi)\left(c_t^{sh} + \bar{c}^{sh}\right)^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}},$$

and

$$p_t^a c_t^a + p_t^m c_t^m + p_t^{sm} c_t^{sm} + p_t^{sh} c_t^{sh} = P_t C_t - \sum_{i=a,m,s} p_t^i \bar{c}^i - p_t^{sh} \bar{c}^{sh}$$

$$\equiv E_t,$$

where E_t stands for the extended total consumption—that is, total consumption plus home production.

The above decomposition indicates that the inter-temporal problem (P2) and the intra-temporal problem (P3) can be solved separately. Also, note that the intra-temporal problem (P3) is the one that causes sectoral transformation among four consumption good sectors.

In Section II, we estimate the intra-temporal problem (P3) using time series data for prices $\left\{p_t^a, p_t^m, p_t^{sm}, p_t^{sh}\right\}$ and extended total consumption E_t.[8] We choose to estimate (P3) instead of the full model (P1) for two reasons. First, we are interested in estimating preference parameters in the model. Given the separation of the two problems shown in this section, it is sufficient to estimate (P3) to obtain consistent estimators of the relevant preference parameters. Second, to estimate the full model (P1), we would need to take a stand on how to bring the investment sector to the data. We know that, in the data, aggregate investment comes from the three market sectors (agriculture, manufacturing, and services) and that the composition has been changing over time. Given this feature of investment, one needs to make some simplification assumptions to model the investment sector. However, depending on the modeling choice, estimates could be different. With this in mind, we avoid making this choice in the inter-temporal problem, and focus only on the estimation of the intra-temporal problem (P3).

D. *Preference Specifications*

The model presented in the previous subsections encompasses the standard models of structural transformation, namely those of Kongsamut, Rebelo, and Xie (2001) and Ngai and Pissarides (2007), with the addition of home production. Since

[8] Regarding the implicit price of home good, p_t^{sh}, we discuss which data we use for it in Section IIIA.

our purpose is to study the effect of home production on structural transformation, we estimate the following four different specifications, which imply different interaction mechanisms of the home and the market sectors.[9]

Model 1: We first impose $\bar{c}^s = \bar{c}^{sh} = 0$. As discussed in Kongsamut, Rebelo, and Xie (2001), the parameter $\bar{c}^s > 0$ can be interpreted as home production of services. Thus, when adding an explicit home production sector to the model, a natural restriction is to impose $\bar{c}^s = 0$. In this way, we can assess whether the home sector can replicate the role played by the non-homothetic parameter in the standard model.

Model 2: In the second specification, we only impose $\bar{c}^{sh} = 0$. This implies that we are allowing for both an explicit home production sector and the standard non-homotheticity effect for services. Thus, the parameter $\bar{c}^s$ simply reflects a non-homothetic nature of services, which is not fully explained by home production.

Model 3: Third, we estimate the specification in which we only impose $\bar{c}^s = 0$. In this case, we allow the non-homotheticity to be different between market and home services through $\bar{c}^{sh}$, while we keep the non-homothetic term for the composite service $\bar{c}^s$ at zero.[10] By doing so, we can assess how much the non-homotheticity in home services $\bar{c}^{sh}$ improves the model's fit to the data by itself.

Model 4: Finally, we estimate the fully unrestricted model. By estimating the first three models, we obtain insights into the role of each non-homothetic component. Here, we have all non-homothetic effects working together.

In the above preference specifications, the parameter $\bar{c}^{sh}$ is motivated by the empirical evidence, which suggests that services categories can have different income elasticities. For instance, Eichengreen and Gupta (2013) shows that the share of modern market services rises faster with income compared to that of the more traditional market services, which can also be produced at home. Although this evidence does not provide insights into the income elasticity of home services, it is reasonable to suppose that home and market services have different income elasticities. If the latter have a larger elasticity, we should expect a parameter $\bar{c}^{sh} < 0$. In this case, the parameter can be interpreted as a minimum requirement of home production that the household has to provide (for instance maintenance and cleaning) before enjoying the rest of home services produced.

II. Estimation

This section describes the estimation. We take a two-step procedure: first, we fix the value of the elasticity of the substitution parameter between home and market

[9] Note that in all specifications, we restrict $\bar{c}^m$ to be zero, as is standard in the literature.

[10] Note that in a CES aggregator with two goods, the presence of a non-homothetic term associated with one of the goods implies that the other good will also display a non-homothetic behavior. This is the case here for home services and market services. On this point, see Moro (2015).

services by using a priori information from the literature; second, we estimate the rest of the parameter values from the data.[11] We explain these steps in detail here.

First Step.—In this step, we fix the value of the parameter γ, which governs the elasticity of substitution between home and market services.[12] In the literature, one set of studies estimates the parameter γ by using fluctuations of aggregate home hours over the business cycles (McGrattan, Rogerson, and Wright 1997; Chang and Schorfheide 2003). Another set of studies, instead, uses household micro data for home hours (Rupert, Rogerson, and Wright 1995; Aguiar and Hurst 2007). The estimated value of the parameter γ ranges between 1.49 and 2.30. One important note here is that all of these estimates correspond to the elasticity of substitution between all market and nonmarket types of consumption. Instead, in our model the parameter only refers to the substitutability between market services and home production. As it seems reasonable to consider that market services are more substitutable with home production than other goods, we set the value of γ equal to 2.3, the highest one estimated in previous studies.[13]

Second Step.—To estimate the rest of the parameters, we first derive equations for the share of each sector in the extended total consumption. Given the the set of (predetermined) variables,

$$\mathbf{x}_t \equiv \left(p_t^a, p_t^m, p_t^{sm}, p_t^{sh}, E_t\right),$$

given γ, and given the rest of the parameters,

$$\boldsymbol{\theta} \equiv \left(\sigma, \bar{c}^a, \bar{c}^s, \bar{c}^{sh}, \omega^a, \omega^m, \omega^s, \psi\right),$$

problem (P3) can be solved for four shares, $\left\{\frac{p_t^j c_t^j}{E_t}\right\}$, where $j \in \{a, m, sm, sh\}$. Since sectoral shares sum up to one, the error covariance matrix becomes singular with four share equations. Thus, we drop one share equation, and finally have the three nonlinear equations to be estimated:

$$\frac{p_t^a c_t^a}{E_t} = f_1\left(\mathbf{x}_t; \boldsymbol{\theta}, \hat{\gamma}\right) + \epsilon_1,$$

$$\frac{p_t^m c_t^m}{E_t} = f_2\left(\mathbf{x}_t; \boldsymbol{\theta}, \hat{\gamma}\right) + \epsilon_2,$$

$$\frac{p_t^{sm} c_t^{sm}}{E_t} = f_3\left(\mathbf{x}_t; \boldsymbol{\theta}, \hat{\gamma}\right) + \epsilon_3,$$

[11] In online Appendix B, we estimate γ together with the rest of the parameters.

[12] Note that γ does not coincide with the elasticity of substitution when non-homothetic parameters appear in the utility function. However, in our estimations, we find that the difference between γ and the true elasticity of substitution is quantitatively very small. Therefore, we consider γ as a measure of the elasticity of substitution.

[13] Our strategy for the choice of the elasticity parameter is the same as the one in Rogerson (2008). In online Appendix B, we run estimations instead by assuming γ is equal to 1.5, the lowest value estimated in the literature. We show that our main results don't change even in that case.

where $\hat{\gamma}$ is the value of the parameter γ from the first step. In Appendix B, we show the derivation of (f_1, f_2, f_3).[14]

To estimate our demand system, we closely follow previous works in the literature: Deaton (1986) and Herrendorf, Rogerson, and Valentinyi (2013). Specifically, we employ the iterated feasible generalized nonlinear least square to estimate the share equations.[15] For the parameters with constraints $(\sigma \geq 0, \omega^a + \omega^m + \omega^s = 1, \omega^i \geq 0, 0 \leq \psi \leq 1)$, we transform them into unconstrained parameters as follows:

$$\sigma = e^{b_1}, \omega^a = \frac{1}{1 + e^{b_2} + e^{b_3}}, \quad \omega^m = \frac{e^{b_2}}{1 + e^{b_2} + e^{b_3}},$$

$$\omega^s = \frac{e^{b_3}}{1 + e^{b_2} + e^{b_3}}, \quad \psi = \frac{e^{b_4}}{1 + e^{b_4}}.$$

After estimating the unconstrained parameters, we transform these back to compute point estimates and standard errors for the original parameters.

III. Data

One of the contributions of this paper is to estimate a structural transformation model with a home sector by using actual home production data for the United States. We follow the income approach recently developed in the literature to construct home production data. Since the approach is based on the value-added method, we focus on consumption value-added shares for our estimation. We explain below how we construct the data for our estimation.

A. *Home Production Data*

The basic idea of the income approach is to compute the value of home production from the market value of input factors: here, home labor L_t^{sh} and home capital K_t^{sh}. Formally, home value added of the household sector is given by

$$\left(r_t^{sh} + \delta_t^{sh}\right)K_t^{sh} + w_t^{sh} L_t^{sh},$$

where r_t^{sh} and δ_t^{sh} are, respectively, the rate of return and the depreciation rate of home capital, and w_t^{sh} is the return on home labor.

For the home capital K_t^{sh}, we use the nominal stock of consumer durables (BEA FA table 8.1).[16] Unlike Bridgman (2013), we don't include gross housing value added in home capital because the value of housing services also shows up in the

[14] See equations (7) through (9) in Appendix B.

[15] This methodology has also been recently used in the estimation of supply systems. See León-Ledesma, McAdam, and Willman (2010).

[16] We use the most recent BEA (2015) and Board of Governors (2015) data. We refer to specific tables in the main text. All BEA data can be downloaded at https://www.bea.gov/. The data from the Board of Governors can be found at FRED website: https://fred.stlouisfed.org.

household's consumption expenditure.[17] For the rate of return on home capital r_t^{sh}, we use the *personal income receipts from assets* (BEA NIPA table 2.1) divided by *total financial assets of the household* (Board of Governors FL152090205) net of *equity in noncorporate business* (Board of Governors FL154090005). For δ_t^{sh}, we use the depreciation of durables (BEA FA table 1.3).

For home labor L_t^{sh}, we use hours spent in home production constructed by Landefeld, Fraumeni, and Vojtech (2009) and Bridgman et al. (2012). These studies use multiple time use survey data and extrapolate them using CPS data on population and labor force status. For the return on home labor w_t^{sh}, we calculate hourly wage by using compensation for employees in the *private households* sector (BEA NIPA table 6.2) and the number of employees in that sector (BEA NIPA table 6.5), assuming that those workers spend 40 hours in working per week.[18]

Finally, Bridgman (2013) deflates nominal home value added with the *price index of gross value added for household sector* (BEA NIPA table 1.3.4) to obtain real home value added. We use this as the price for home value added $\{p_t^{sh}\}$ in our estimations below. Thus, except for the construction of home capital K_t^{sh}, we closely follow the methodology in Bridgman (2013).

B. *Other Data*

Value-Added Consumption and Price Index.—The data for value-added consumption and the corresponding price indices for agriculture, manufacturing, and services are from Herrendorf, Rogerson, and Valentinyi (2013). The advantage of using these data is that value-added consumption is computed from final consumption expenditure by using the US input-output matrix in order to avoid investment components being included in consumption value-added data.[19]

Durable Goods.—As mentioned above, we consider all durable goods as inputs for home production. Therefore, it is reasonable to remove the value of durables from the value-added consumption data because otherwise households have durables both as consumption goods and as capital inputs for home production. Since the value of durables in consumption expenditure data consists of the value added from the three market sectors, we again follow the approach in Herrendorf, Rogerson, and Valentinyi (2013) to remove the value of durables from value-added consumption. That is, we first decompose the value of final-expenditure durables into the value added of each sector using an input-output matrix, and then subtract those values from the consumption value added of each sector.

In the robustness Section IVB, we relax the assumption that all durables are used as investment in home capital. That is, we consider the case in which some durables are treated as consumption goods, and the rest are investment goods for home

[17] This is the same approach taken, for instance, in Bridgman, Duernecker, and Herrendorf (2015).

[18] Duernecker and Herrendorf (2015) also use compensation for employees in the private households sector to compute the hourly wage rate for home labor. As they note, the main assumption here is that the marginal product of household workers is the same as the marginal product of a non-household worker who is doing household work.

[19] Several papers in this literature assume that all investment is produced in the manufacturing sector. However, the total value of investments exceeds the total value of manufacturing goods from 1999 onward in BEA's data.

Table 1—Sectoral Share Estimation Results

	1 (1)	2 (2)	3 (3)	4a (4a)	4b (4b)
σ	0.0528	0.0259	0.00331	0.00459	
	(0.0291)	(0.0202)	(0.00174)	(0.00348)	
$\bar{c}^a$	−176.0	−177.3	−154.7	−120.1	−129.0
	(3.603)	(3.856)	(9.276)	(15.51)	(13.65)
$\bar{c}^s$		71.14		4,536.3	4,360.8
		(31.22)		(368.1)	(323.0)
$\bar{c}^{sh}$			−3,292.4	−5,232.1	−5,135.3
			(121.3)	(133.8)	(182.8)
ω^a	0.00000158	0.0000415	0.00133	0.00329	0.00260
	(0.00000267)	(0.000128)	(0.000965)	(0.00120)	(0.00108)
ω^m	0.180	0.179	0.200	0.155	0.157
	(0.00351)	(0.00562)	(0.00298)	(0.00382)	(0.00363)
ω^s	0.820	0.821	0.798	0.841	0.840
	(0.00351)	(0.00550)	(0.00266)	(0.00391)	(0.00356)
ψ	0.548	0.550	0.591	0.628	0.625
	(0.00314)	(0.00342)	(0.00303)	(0.00525)	(0.00496)
Observations	64	64	64	64	64
AIC	−1,180.3	−1,177.7	−1,226.8	−1,300.7	−1,303.3
BIC	−1,148.7	−1,139.8	−1,188.9	−1,256.5	−1,265.4
$RMSE^a$	0.004	0.004	0.004	0.004	0.004
$RMSE^m$	0.009	0.008	0.012	0.007	0.007
$RMSE^{sm}$	0.067	0.067	0.042	0.027	0.027
$RMSE^{sh}$	0.065	0.065	0.037	0.028	0.029

Notes: Robust standard errors are in parentheses. *AIC* is Akaike Information Criterion. *BIC* is Bayesian Information Criterion. $RMSE^j$ is the root mean squared error for j-sector's share equation.

capital. For example, we consider goods like jewelry and watches as directly consumed by households, while goods like home appliances form part of home capital. As we will show later, our estimation results are not affected by the relaxation of this assumption.

In the estimation, we focus on the time period between 1947 and 2010, due to the availability of consumption value-added data. In order to calculate four sector shares (agriculture, manufacturing, services, and home) in extended consumption value added, we combine consumption value-added data with value added of the home sector. One important assumption made here is that goods produced at home are not used for investments.

IV. Estimation Results

A. *Benchmark Results*

Table 1 summarizes estimation results for our benchmark case. In columns 1 through 4, we report the estimation results of Models 1 to 4, which we described in Section ID. In column 5, we also report the results when we impose the constraint $\sigma = 0$ on Model 4. We name the model without the constraint as Model 4a, and the one with the constraint, Model 4b.

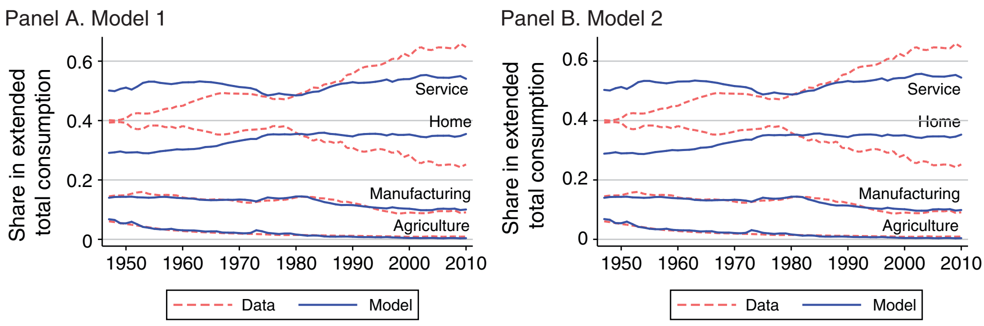

Figure 2. Fitted Sectoral Shares for Model 1 ($\bar{c}^s = \bar{c}^{sh} = 0$) and Model 2 ($\bar{c}^{sh} = 0$)

From the perspectives of Akaike and Bayesian Information Criteria (AIC and BIC) reported in Table 1, it is evident that neither Model 1 or 2 (columns 1 and 2) display a better performance than Model 3 or 4a (columns 3 and 4). The poor fit of Models 1 and 2 is also visually presented in Figure 2, indicating that neither of them can correctly capture the increasing trend of market services and the decreasing trend of home services. These facts imply that the common specification in the literature, which assumes the same income elasticity of market and home services (i.e., $\bar{c}^{sh} = 0$), cannot explain why the demand for market services has increased relative to home services over the period. Also, from the estimation result of Model 2, it is clear that the non-homotheticity term on aggregate services $\bar{c}^s$ doesn't help to solve the issue by itself.[20]

We now turn to discuss Model 3 and Model 4a. There are three points worth emphasizing here. First, as discussed above, Models 3 and 4a display a better fit than Models 1 and 2, suggesting that the non-homothetic term $\bar{c}^{sh}$ is key to account for the trends in both market and home service shares.[21] Second, by comparing the performances of Model 3 and Model 4a, we note that the non-homothetic term on aggregate services $\bar{c}^s$ plays an important role once the non-homothetic term on home services $\bar{c}^{sh}$ is introduced. This is also visually shown in Figure 3. When $\bar{c}^s$ is constrained at zero (Model 3), the model is not able to produce enough divergence in the patterns of home and market service shares. Instead, when $\bar{c}^s$ is unconstrained (Model 4a), the model's performance improves. This is because, in the former case, there is only one non-homotheticity parameter controlling the relative trends of two share series, but in the latter case, there are two parameters shaping those trends.

Third, when both the non-homotheticity term for aggregate services $\bar{c}^s$ and the one for home services $\bar{c}^{sh}$ are introduced, the value of σ is no longer statistically significantly different from zero. The point estimator of σ is 0.00459, and the value of the heteroscedasticity robust standard error is 0.00348. This implies that the utility function takes a Leontief specification in terms of agricultural, manufacturing,

[20] In fact, the AIC and BIC suggest that Model 1 performs better than Model 2.

[21] Ngai and Pissarides (2008) generate a rise of the market services share in a model with home production through homothetic preferences and differential TFP growth across sectors. Our results instead suggest that a non-homothetic component on home production is key to quantitatively account for the actual rise of the market services share in the United States in a model with a home sector.

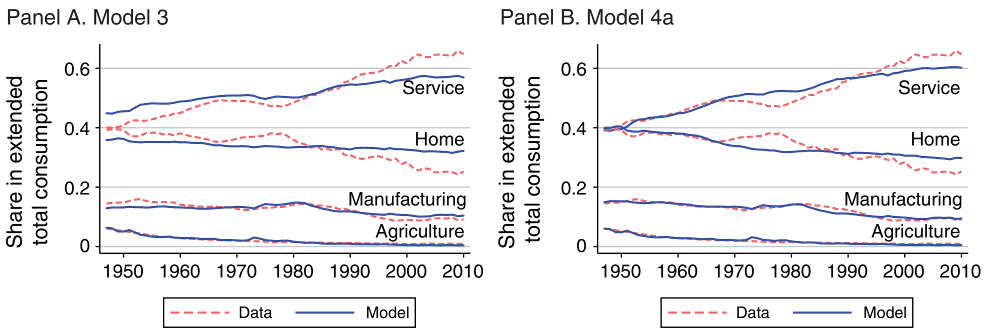

FIGURE 3. FITTED SECTORAL SHARES FOR MODEL 3 ($\bar{c}^s = 0$) AND MODEL 4A (*no restrictions*)

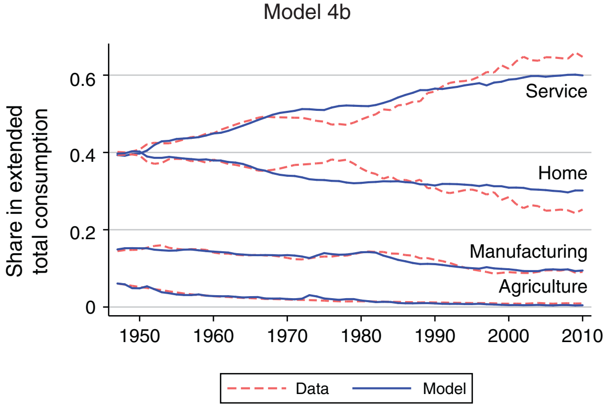

FIGURE 4. FITTED SECTORAL SHARES FOR MODEL 4B ($\sigma = 0$)

and aggregate services. Notably, this result for σ is similar to those in Buera and Kaboski (2009) and Herrendorf, Rogerson, and Valentinyi (2013). Given that the point estimator of σ is not statistically significantly different from zero, we restrict the value of σ to zero, and run the estimation of Model 4b (column 5 in Table 1). The result shows that, while the root mean squared errors are unchanged, the AIC and the BIC decrease, implying that this specification is the most preferred in terms of those measures. Therefore, we use Model 4b for our counterfactual experiments in the following subsections.[22]

B. *Robustness*

Here, we discuss the robustness of the benchmark results. For brevity, we report all estimates in Appendix A.

[22]To interpret the estimated non-homothetic terms $\bar{c}^a$, $\bar{c}^s$, and $\bar{c}^{sh}$ for Model 4b, we compute their values relative to the consumption level of each good in 1947. These are 0.81 for $(-\bar{c}^a/c^a)$, 0.85 for $(\bar{c}^s/c^s)$, and 0.73 for $(-\bar{c}^{sh}/c^{sh})$.

Table 2—Durable Good Categories

	Good Categories in NIPA table 2.4.5
Consumption goods	video, audio, photographic, and information processing equipment and media, sporting equipment, supplies, guns, and ammunition, sports and recreational vehicles, recreational books, musical instruments, jewelry and watches, luggage and similar personal items, telephone and facsimile equipment
Investment goods	furniture and furnishings, household appliances, glassware, tableware, and household utensils, tools and equipment for house and garden, therapeutic appliances and equipment, education books
Motor vehicles	new motor vehicles, net purchases of used motor vehicles, motor vehicle parts and accessories

Splitting Durable Goods.—As we discussed in Section III, we consider all durable goods as investment in home capital in the benchmark case. However, while some types of goods are more likely to be used for home production (e.g., home appliances), some others are more naturally assigned to consumption (e.g., jewelry and watches). Therefore, it seems reasonable to check whether our estimation results are robust when we relax the assumption that all durables are used as capital inputs for home production.

For this purpose, we first classify the final durable good expenditure in two categories: direct consumption goods and capital inputs for home production. Then, we calculate consumption value added from the former and use the latter to compute home value added. We refer to BEA's NIPA table 2.4.5 when dividing final durable good expenditures into the two categories. We then apply the input-output matrices in Herrendorf, Rogerson, and Valentinyi (2013) to those which we classified as consumption goods in order to convert consumption expenditure into consumption value added. The created consumption value-added data are then added to the consumption value added of each market sector. We also refer to BEA's FA table 8.1 when constructing the stock of durable goods, which is consistent with the way we split them in consumption expenditure data.[23] The data of the stock are then used to construct home capital. Table 2 shows our classification of durable goods into the two categories. One type of good that is likely to be used extensively both for consumption and for home capital is motor vehicles. Therefore, for motor vehicles, we consider two cases: first, we include them in consumption goods (Case 1); and second, we consider them as home capital investment (Case 2).

Tables A1 and A2 in Appendix A present the results for each case. As shown in the tables, none of the findings in our benchmark estimation change significantly in both cases. Notably, our finding that the non-homotheticity parameter $\bar{c}^{sh}$ significantly improves the model's performance is fairly robust even after we introduce the new definitions for home capital goods.

[23] NIPA table 2.4.5 and FA table 8.1 have almost the same structure in terms of the classification of durable goods. Therefore, it is possible to construct the stock of durable goods consistent with the way we split durable goods in the consumption expenditure data.

Table 3—Labor Productivity Growth Rate: Home and Market Services

	Labor productivity growth rate (percent)		
Time period	Home services	Market services	Difference
1947–1978	2.4	1.7	0.7
1979–2010	−0.4	1.0	−1.4

Notes: The labor productivity for market services is calculated by deflating total valued added of the service sector (BEA's GDP-by-industry table) by the price index of the sevice sector (Herrendorf, Rogerson, and Valentinyi 2013), and by dividing it by hours worked by full-time and part-time employees in the service sector (NIPA table 6.9).

Excluding Government Consumption.—Government consumption is externally imposed on the household, and there is not a price at which households optimally decide the quantity to purchase. Therefore, it doesn't seem to be fully appropriate to study structural transformation by considering consumption purchased by the government sector. For this reason, we remove government spending from consumption value added data, and reestimate our model to check the robustness of our benchmark results. In this exercise, we are implicitly assuming that households are taxed by the government to run a balanced budget, and that government spending does not provide utility to the households. Table A3 in Appendix A presents estimation results when we exclude government's spending from the consumption value-added data. Again, none of the findings in our benchmark estimation change significantly, even when we control for the government's spending.

V. Counterfactual Experiment

As documented in Bridgman (2013), home labor productivity in the United States exhibits a remarkable slowdown in its growth after 1978. During the period 1947–1978, the gowth rate of home labor productivity is 2.4 percent, while that of market services is 1.7 percent, as reported in Table 3. In the following period 1979–2010, however, the growth rate of home labor productivity is −0.4 percent, which is below that of market services, 1 percent.[24] Given its magnitude and long lasting duration, it is reasonable to ask how large the quantitative effect of this slowdown is for the process of structural transformation. In this section, we address this question by running a counterfactual experiment, in which we assume that, during the period 1979–2010, the average growth rate differential between home labor productivity and market services labor productivity is kept equal to that in the period 1947–1978.

More precisely, we assume that in the household problem, all market prices and total expenditure evolve as observed in the data, while the price of the home good evolves differently from the data due to a counterfactual pattern of home labor

[24] To precisely date the slowdown, we test for multiple structural breaks using the approach proposed in Bai and Perron (1998, 2003). We find that, at 1 percent significance level, there is a break between 1978 and 1979, after which the growth rate of home labor productivity decreases by 2.8 percentage points. See online Appendix D for details.

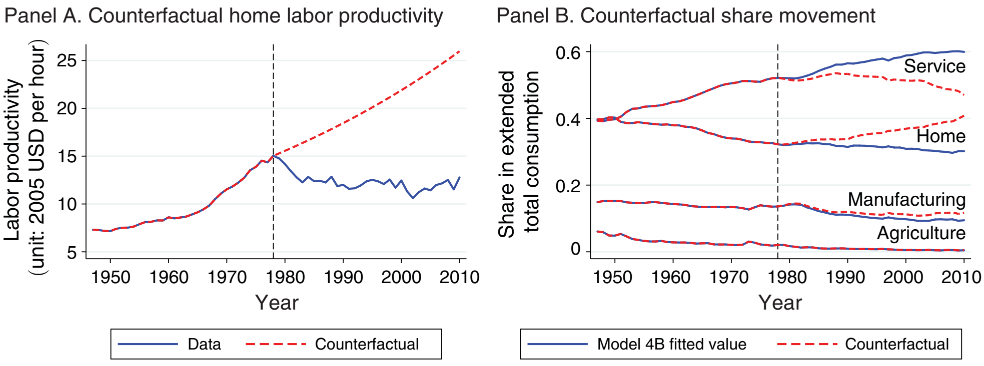

Figure 5. Counterfactual Experiment: No Slowdown in Home Labor Productivity

productivity A_t^{*sh}. As the growth difference in the period 1947–1978 is 0.7 percentage points, and market services productivity grows at 1 percent in the 1979–2010 period, we assume that home labor productivity grows at 1.7 percent in the counterfactual. Then, by using the first-order conditions of the firm in the home sector, we can derive

$$\frac{\Delta p_t^{sh}}{p_t^{sh}} = \frac{\Delta w_t}{w_t} - \frac{\Delta A_t^{*sh}}{A_t^{*sh}}, \tag{6}$$

which defines the relationship between the growth rate of the home price and that of home labor productivity.[25] Using equation (6), we can calculate the counterfactual price of the home good from the counterfactual home labor productivity. To run the experiment, we use Model 4b, which provides the best fit for the data. The outcome of the exercise is displayed in the right panel of Figure 5.

Without the slowdown in home labor productivity, the divergence between the share of market services and the home share over the period is substantially reduced. Thus, this experiment suggests that, holding other conditions equal, the slowdown in home labor productivity is crucial in accounting for the whole rise of the market services share.

The first three columns in Table 4 report the extended consumption shares in the benchmark estimation (the fitted values of Model 4b) and in the counterfactual for the year 2010. The market services share is 0.60 in the benchmark and 0.47 in the counterfactual experiment. This difference is compensated by the home share, which is 0.30 in the benchmark and 0.41 in the counterfactual. These numbers

[25] Using the first-order conditions of the firm in the home sector, we can derive

$$p_t^{sh} = \frac{w_t}{(1-\alpha)A_t^{sh}\left(\dfrac{K_t^{sh}}{L_t^{sh}}\right)^{\alpha}} = \frac{w_t}{(1-\alpha)\left(\dfrac{Y_t^{sh}}{L_t^{sh}}\right)} = \frac{w_t}{(1-\alpha)A_t^{*sh}}.$$

By taking total differentiation on both sides, we reach the equation in the text.

TABLE 4—COUNTERFACTUAL EXPERIMENT: NO SLOWDOWN IN HOME LABOR PRODUCTIVITY

	Ext. consumption share			Consumption share			Consumption per capita		
	Bench	CF	Δpercent	Bench	CF	Δpercent	Bench	CF	Δpercent
Agriculture	0.005	0.005	8.5	0.006	0.008	28.0	228	247	8.5
Manufacturing	0.095	0.117	23.7	0.135	0.198	45.9	4,751	5,877	23.7
Market services	0.599	0.470	−21.6	0.858	0.794	−7.5	30,124	23,629	−21.6
Home services	0.302	0.408	35.3	—	—	—	15,159	39,609	161.3

Notes: Consumption per capita is in 2005 US dollars. The numbers in "Δpercent" columns are percent changes from the benchmark fitted value (Model 4b).

suggest a large substitution of market services by home services without the slowdown in home labor productivity. A similar result holds for the services share when we look at the (market) consumption shares reported in the second three columns in Table 4. Services is 0.86 in the benchmark and 0.80 in the counterfactual. This difference amounts to a 7.5 percent decrease of the market service share. The last three columns in the table report consumption per capita in 2005 US dollars. As market prices do not change in the counterfactual, the patterns are the same as those of the extended consumption shares except for home services. To conclude, the results in the counterfactual experiment indicate that the slowdown in the home labor productivity has quantitatively a significant impact on the rise of the market service sector over the period of the analysis.

VI. Disaggregating the Service Sector

In our benchmark specification in Section I, we assume that all market services enter the aggregator with home services, thus implicitly assuming that they are all substitutable with home services to the same extent. Although this is the specification most commonly used in the literature (see, for instance, Rogerson 2008, Ngai and Petrongolo 2013, and Rendall 2015), one might think that some market services do not have a home counterpart. For instance, finance, health, and educational services don't seem to be substitutable with home services. Therefore, it is important to further disaggregate market services into home substitutables and non-substitutables, and to write and estimate a model which explicitly considers these two sectors. In this section, we explore this possibility.

A. *Model*

We assume the same general structure of the model as in Section I, and introduce two types of market services. The consumption index of the representative household in period t becomes

$$C_t = \left(\sum_{i=a,m,s} \left(\omega^i\right)^{\frac{1}{\sigma}} \left(c_t^i + \bar{c}^i\right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}.$$

Here, c_t^a stands for the household's consumption of agricultural goods, c_t^m of manufacturing goods, and c_t^s for services. Services are a composite of *modern* services c_t^{sn} and *traditional* services c_t^{sc}:

$$c_t^s = \left[\phi\left(c_t^{sn}\right)^{\frac{\rho-1}{\rho}} + (1-\phi)\left(c_t^{sc} + \bar{c}^{sc}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}.$$

Modern services are interpreted as those that cannot be produced at home. Instead, traditional services are a composite of home services, c^{sh}, and services produced in the market with a good home produced counterpart, c_t^{sm}:

$$c_t^{sc} = \left[\psi\left(c_t^{sm}\right)^{\frac{\gamma-1}{\gamma}} + (1-\psi)\left(c_t^{sh} + \bar{c}^{sh}\right)^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}.$$

The budget constraint of the household is

$$p_t^a c_t^a + p_t^m c_t^m + p_t^{sn} c_t^{sn} + p_t^{sm} c_t^{sm} + p_t^{sh} c_t^{sh} = E_t,$$

where now p_t^{sn} is the price of modern services, p_t^{sm} is the price of traditional services in the market and, as before, p_t^{sh} is the implicit price of the home good.[26] We estimate two versions of the model.[27]

Model 5: We impose $\bar{c}^{sh} = 0$, which implies the same income elasticity for traditional market services and home services.

Model 6: We estimate the fully unrestricted model so that income elasticity is allowed to be different for the three types of services.

B. *Data*

In order to estimate the model presented in Section VIA, we need to construct the consumption value added and corresponding price data for the modern and traditional market service sectors. To create the consumption value-added data, we follow the approach in Herrendorf, Rogerson, and Valentinyi (2013). That is, first, within final consumption expenditure data, we define two categories, modern and traditional market services. Second, we remove the distributional costs from the final consumption expenditure on goods and move them into expenditure on modern services.[28] Third, we create the input-output matrices, which have the modern and traditional market service sectors. Finally, we apply the input-output matrices to final consumption expenditure to convert them into consumption value added.

[26] Note that the separation between the inter-temporal problem and the intra-temporal problem also applies here.
[27] Again, in all specifications, we assume $\bar{c}^m$ is equal to zero.
[28] This procedure converts final consumption expenditure measured in purchaser's prices into the one measured in producer's prices. We move distributional costs to the modern service sector because our definition of modern services includes transportation services as shown later.

To define traditional services that are substitutable for home production, we look at home production activities in the time use surveys that are used for the calculation of the home hours we adopt in this paper. For the calculation of the home hours, we follow Landefeld, Fraumeni, and Vojtech (2009) and Bridgman et al. (2012), who select seven categories, "cooking," "house work," "odd jobs," "gardening," "shopping," "child care," and "travel," as home production activities. To define traditional services, we choose service categories in the consumption expenditure data that correspond to the seven home production activities in the time use surveys. In the NIPA table 2.4.5, "cooking" and "shopping" activities can be mapped to "food services and accommodations" and "personal care and clothing services" categories; and "house work," "odd jobs," and "gardening" activities can be mapped to the "household maintenance" category. In their calculation of the home hours, Landefeld, Fraumeni, and Vojtech (2009) and Bridgman et al. (2012) define the "travel" activity as travels related to the other six home production activities. Therefore, we don't consider a specific service category in the consumption expenditure data which corresponds to the "travel" activity.[29] Finally, we note that the "child care" activity could be mapped to "education services" in the consumption expenditure data. However, we decided not to include "education services" in the traditional services because child care is only a small fraction of the total education services, and it is not possible to separate child care services from other education services in the input-output matrices.[30] Therefore, we select the three categories, "food services and accommodations," "personal care and clothing services," and "household maintenance," as traditional services and the rest as modern services, as summarized in Table 5. In order to create the input-output matrices, we apply a similar categorization. The details on how we construct the input-output matrices are documented in online Appendix C.

To create the corresponding prices, we use nominal value added, chain-weighted value-added quantities, and chain-weighted value-added prices at industry level from BEA's GDP-by-industry table. Since chain-weighted quantities are not additive, we apply the so-called cyclical expansion procedure to aggregate quantities into the four categories (agriculture, manufacturing, modern market services, and traditional market services).[31] We then use them to calculate the aggregate prices for the four categories. In online Appendix C, we describe how we construct prices in detail.

C. *Estimation Results*

Columns 1 and 2 in Table 6 summarize the estimation results for Models 5 and 6, respectively. Also, Figures 6 and 7 provide their graphical fit of the data.

First, note that in column 1 of Table 6, the non-homotheticity parameter on traditional services, $\bar{c}^{sc}$, is estimated to be negative. This result implies that traditional

[29] Also, note that a large fraction of "transportation services" in the consumption expenditure data includes "air transportation," "rail transportation," "water transportation," and "truck transportation," which do not appear to be the services substitutable to the category "travel" of home production.

[30] Child care services are included in the subcategory, "nursery, elementary, and secondary schools" in the consumption expenditure data (the NIPA table 2.4.5). In the 2010 data, "nursery, elementary, and secondary schools" makes up only 15 percent of the total education service expenditure.

[31] For an explanation of the cyclical expansion procedure, see Herrendorf, Rogerson, and Valentinyi (2013).

Table 5—Modern and Traditional Market Services in the Consumption Expenditure

	Service categories in NIPA table 2.4.5
Modern market services	Housing and utilities (49), health care (60) Transportation services (68), recreation services (76) Financial services and insurance (86), communication (96) Education services (100), professional and other services (121) Social services and religious activities (120)
Traditional market services	Food services and accommodations (81) Personal care and clothing services (105), household maintenance (107)

Note: The numbers in parentheses in the above table correspond to the line numbers in NIPA table 2.4.5.

Table 6—Disaggregated Service Sector: Estimation Results

	Disagg. of services 5 (1)	Disagg. of services 6 (2)
σ	0.000912 (0.000133)	0.101 (0.0181)
ρ	3.791 (0.0779)	3.422 (0.0310)
$\bar{c}^a$	−154.3 (6.348)	−134.8 (6.133)
$\bar{c}^s$	3,392.2 (229.4)	3,566.8 (184.5)
$\bar{c}^{sc}$	−2,455.8 (67.08)	−388.6 (47.21)
$\bar{c}^{sh}$		−3,254.7 (109.0)
ω^a	0.000877 (0.000502)	0.00266 (0.000638)
ω^m	0.196 (0.00402)	0.185 (0.00396)
ω^s	0.804 (0.00419)	0.812 (0.00434)
ψ	0.252 (0.00183)	0.290 (0.00286)
ϕ	0.489 (0.00312)	0.486 (0.00142)
Observations	64	64
AIC	−1,832.5	−1,869.2
BIC	−1,775.7	−1,806.0
$RMSE^a$	0.004	0.004
$RMSE^m$	0.008	0.009
$RMSE^{sn}$	0.011	0.010
$RMSE^{sm}$	0.010	0.009
$RMSE^{sh}$	0.013	0.011

Note: Robust standard errors are in parentheses.

services have a lower income elasticity than modern services. In addition, column 2 in Table 6 shows that, in Model 6, which performs better than Model 5 in terms of AIC and BIC, the non-homotheticity parameter on home services, $\bar{c}^{sh}$, is also estimated to be negative. This result suggests that home production displays a

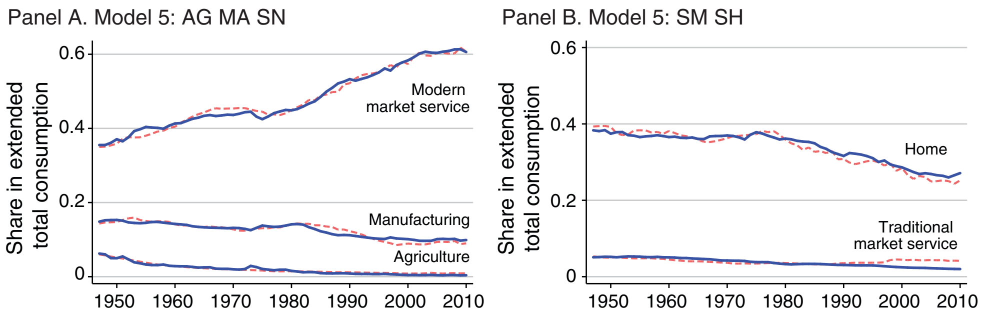

FIGURE 6. DISAGGREGATED SERVICE SECTOR: MODEL 5 ($\bar{c}^{sh} = 0$)

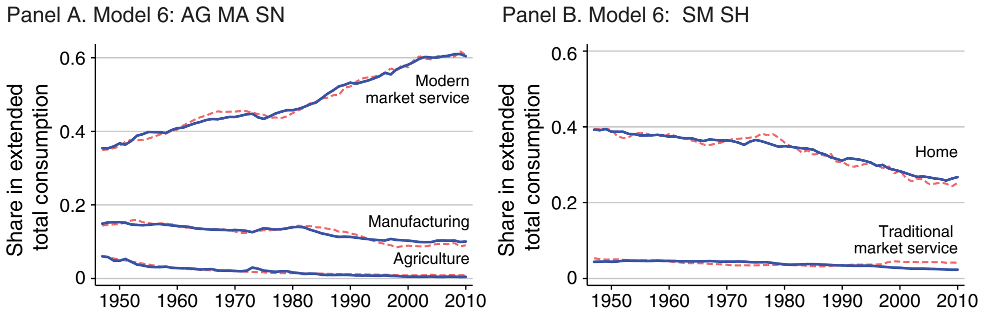

FIGURE 7. DISAGGREGATED SERVICE SECTOR: MODEL 6 (*no restrictions*)

lower income elasticity than the rest of traditional services (i.e., market traditional services).

Thus, the disaggregation of market services provides two insights: first, traditional services display a lower income elasticity with respect to modern services. Second, within traditional services, home services exhibit the lowest income elasticity. These results are consistent with that in the benchmark case, in which home services (a subset of traditional services) display a lower income elasticity relative to total market services (the sum of modern and traditional market services).

Finally, note that, even after we disaggregate the market service sector into modern and traditional, the point estimate of σ is close to zero as in the benchmark case. Instead, the parameter governing the elasticity of substitution between modern and traditional services, ρ, is found to be larger than 1 and between 3.4 and 3.8 depending on the specification. This value of ρ implies high substitutability between modern and traditional services.

D. *Counterfactual Experiment*

In this subsection, we use the estimate of Model 6 and run the same counterfactual experiment as in Section V.[32] That is, we analyze the movement of the sector shares

[32] We use Model 6 in the counterfactual as it provides the best fit of the data in terms of AIC and BIC.

Table 7—Counterfactual Experiment in the Disaggregated Case

	Ext. consumption share			Consumption share			Consumption per capita		
	Bench	CF	Δpercent	Bench	CF	Δpercent	Bench	CF	Δpercent
Agriculture	0.005	0.005	7.3	0.006	0.010	65.1	228	245	7.3
Manufacturing	0.100	0.123	22.2	0.137	0.258	87.9	5,050	6,170	22.2
Market services	0.627	0.349	−44.4	0.857	0.732	−14.5	31,535	17,519	−44.4
Modern	0.604	0.325	−46.2	0.825	0.682	−17.3	30,369	16,334	−46.2
Traditional	0.023	0.024	1.6	0.032	0.050	56.3	1,166	1,185	1.6
Home services	0.268	0.524	95.8	—	—	—	13,448	50,850	278.1

Notes: Consumption per capita is in 2005 US dollars. The numbers in "Δpercent" columns are percent changes from the benchmark fitted value (Model 6).

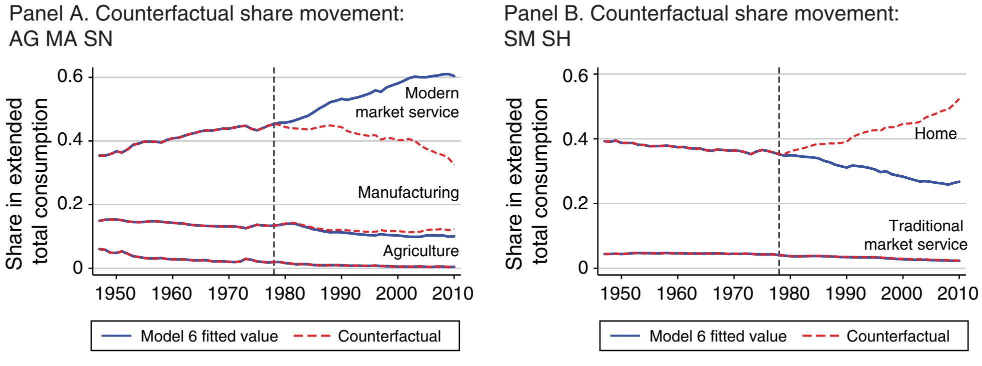

Figure 8. Counterfactual Experiment: Disaggregated Case

assuming that, during the period 1979–2010, the average growth rate differential between home productivity and total market services productivity is the same as that in the period 1947–1978. The results of this counterfactual experiment are reported in Table 7. The movements of shares are shown in Figure 8.

Even in the disaggregated case, we obtain a significant rise of the home service share (95.8 percent) and a sharp decline of the market service share (−44.4 percent) in extended total consumption. These effects are even larger than those in the benchmark, because we estimate a high value of the parameter ρ, which implies high substitutability between modern and traditional services. Therefore, we observe a significant decline of market services, while the responses of the other shares (agriculture and manufacturing) are similar to those in the benchmark case.[33] These results in the disaggregated model confirm that in a context of structural transformation the evolution of home labor productivity has substantial effects for the evolution of market shares.

[33] Note that, while modern market service share declines substantially (−46.2 percent), the traditional market service share increases slightly (1.6 percent). This is due to the negative non-homotheticity term on home services, $\bar{c}^{sh}$. When the home labor productivity increases, there is an income effect since the household becomes richer. This effect increases the demand for traditional market services relative to home services because of the non-homotheticity. While there is a substitution effect that decreases traditional market services due to the lower price of home services, the effect is dominated by the income effect.

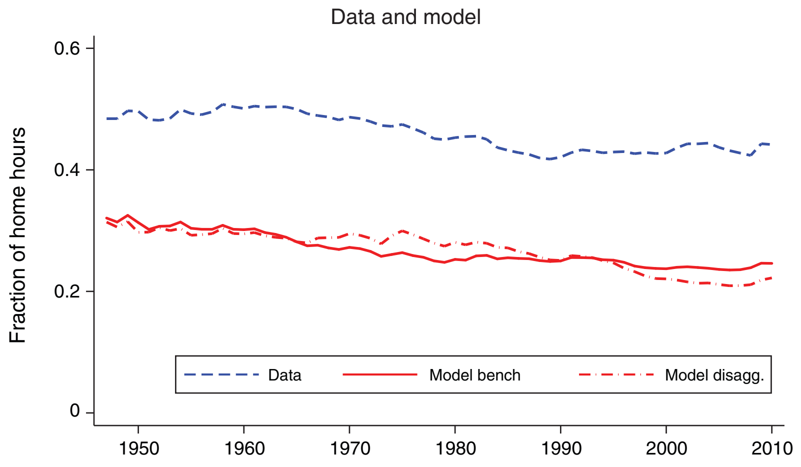

FIGURE 9. FRACTION OF HOME HOURS IN TOTAL WORKING HOURS

Notes: The home and market hours data are for all individuals, age 25 to 64, in the United States. The data are taken from Ramey and Francis (2009).

VII. Implications for Home and Market Hours

Several studies in the literature (Aguiar and Hurst 2007, Ramey 2009, and Ramey and Francis 2009) have documented changing patterns of hours spent in market and home activities in the United States over the second half of the last century. As these changes might reflect the effects of structural transformation, we investigate here whether our model predicts an evolution of home hours that is consistent with that observed in the data. To do this, we generate the fraction of home hours in total working hours in the model, and compare it with the one in the data.

We use the data on weekly market and home hours from Ramey and Francis (2009) to calculate the fraction of home hours. This is the only dataset of household's time use that covers the entire period of our analysis, 1947 through 2010, for both home and market hours.[34] We compute the model's counterpart of the fraction of home hours as the share of the home value added in the extended GDP.[35] Figure 9 plots the fraction of home hours in total working hours in the model and in the data. The two lines at the bottom of the figure are the benchmark model (solid line) and the disaggregated model (dashed line), respectively. The dashed line at the top of the figure is the data. Note that both the benchmark and disaggregated models replicate the declining trend in the fraction of home hours in the data reasonably well.

Although the models perform well in replicating the trend in hours, they are not able to match the level of the fraction of home hours. The reason for this discrepancy lies in the fact that in standard models of structural transformation, the value-added

[34] Ramey and Francis (2009) combine data from multiple sources, and develop comprehensive measures of time spent in market work, home production, schooling, and leisure in the United States, from 1900 to 2006. Their updated data series cover the period through 2012.

[35] The underlying assumption of this calculation is that there are no factor distortions across sectors. This assumption implies that the value-added share and the labor share in each sector are equal in equilibrium.

share and the labor share are equal in equilibrium. Therefore, as long as there are differences in the two types of shares in the data, the model cannot account for both types at the same time.[36] As suggested by Buera and Kaboski (2009), these differences in the data can arise from sectoral differences in human capital or factor distortions across sectors. By incorporating those elements in our model, one might potentially be able to account for both types of shares at the same time. This exercise is beyond the scope of our paper and we leave it for future research.

VIII. Conclusion

In this paper, we present a model of structural transformation with a home production sector and estimate it by using US data. We find that the specification of the model with a different degree of non-homotheticity between home and market services provides the best fit of the data. In particular, the estimation provides an income elasticity of home services lower than that of market services. This is in line with recent empirical evidence suggesting that the share of market services that can also be produced at home grows more slowly with income compared to that of market services which don't have home counterparts.

The estimated model is then used to run a counterfactual experiment. In particular, we measure the contribution of the slowdown in home productivity growth to the rise of the market services share in the United States. We find that without the slowdown, the magnitude of structural transformation is significantly lower. This result suggests that home productivity plays an important role for structural transformation.

Appendix A: Additional Tables

Table A1—Splitting Durable Goods, Case 1: Estimation Results

	1 (1)	2 (2)	3 (3)	4a (4)	4b (5)
σ	0.0747 (0.0351)	0.00186 (0.000473)	0.000144 (0.0000618)	0.000176 (0.0000501)	
$\bar{c}^a$	−177.0 (3.837)	−177.7 (3.571)	−150.4 (8.326)	−128.6 (12.36)	−128.6 (11.63)
$\bar{c}^s$		1,606.4 (322.7)		3,817.1 (351.3)	3,618.9 (286.0)
$\bar{c}^{sh}$			−3,730.9 (128.9)	−5,222.8 (168.3)	−5,159.8 (134.8)
ω^a	0.0000122 (0.0000249)	0.00000753 (0.0000150)	0.00186 (0.000910)	0.00279 (0.000953)	0.00289 (0.000946)
ω^m	0.191 (0.00432)	0.177 (0.00469)	0.216 (0.00254)	0.173 (0.00430)	0.175 (0.00376)

(*continued*)

[36] This is an important shortcoming in the standard structural change models that try to account for the evolution of value-added shares as discussed in Buera and Kaboski (2009) and Herrendorf, Rogerson, and Valentinyi (2014). This implies that the model might deliver a different set of results if estimated using the labor share data.

Table A1—Splitting Durable Goods, Case 1: Estimation Results (*continued*)

	1 (1)	2 (2)	3 (3)	4a (4)	4b (5)
ω^s	0.809 (0.00429)	0.823 (0.00470)	0.782 (0.00280)	0.824 (0.00409)	0.822 (0.00359)
ψ	0.558 (0.00359)	0.559 (0.00343)	0.613 (0.00378)	0.646 (0.00662)	0.644 (0.00604)
Observations	64	64	64	64	64
AIC	−1,167.0	−1,159.0	−1,228.1	−1,297.4	−1,299.2
BIC	−1,135.4	−1,121.1	−1,190.2	−1,253.2	−1,261.2
$RMSE^a$	0.004	0.004	0.004	0.004	0.004
$RMSE^m$	0.008	0.008	0.012	0.007	0.007
$RMSE^{sm}$	0.069	0.065	0.039	0.027	0.027
$RMSE^{sh}$	0.068	0.070	0.034	0.029	0.029

Notes: AIC is Akaike Information Criterion. *BIC* is Bayesian Information Criterion. $RMSE^j$ is the root mean squared error for *j*-sector's share equation. Robust standard errors are in parentheses.

Table A2—Splitting Durable Goods, Case 2: Estimation Results

	1 (1)	2 (2)	3 (3)	4a (4)	4b (5)
σ	0.140 (0.0375)	0.0188 (0.0109)	0.00163 (0.00115)	0.0133 (0.00404)	
$\bar{c}^a$	−184.4 (3.936)	−179.9 (3.351)	−150.1 (9.708)	−133.4 (10.71)	−129.8 (10.64)
$\bar{c}^s$		−904.1 (198.6)		3,754.8 (267.3)	3,635.2 (303.2)
$\bar{c}^{sh}$			−3,935.1 (123.2)	−5,127.9 (120.6)	−5,118.6 (126.1)
ω^a	0.0000177 (0.0000269)	0.0000114 (0.0000331)	0.00221 (0.00102)	0.00265 (0.000932)	0.00294 (0.000881)
ω^m	0.203 (0.00544)	0.224 (0.00447)	0.233 (0.00308)	0.186 (0.00384)	0.188 (0.00412)
ω^s	0.797 (0.00547)	0.776 (0.00446)	0.765 (0.00280)	0.811 (0.00420)	0.809 (0.00423)
ψ	0.572 (0.00238)	0.569 (0.00737)	0.634 (0.00584)	0.662 (0.00527)	0.663 (0.00507)
Observations	64	64	64	64	64
AIC	−1,151.0	−1,153.4	−1,216.7	−1,279.9	−1,281.5
BIC	−1,119.4	−1,115.5	−1,178.8	−1,235.6	−1,243.5
$RMSE^a$	0.005	0.004	0.004	0.004	0.004
$RMSE^m$	0.009	0.010	0.013	0.008	0.008
$RMSE^{sm}$	0.070	0.071	0.038	0.028	0.027
$RMSE^{sh}$	0.069	0.068	0.034	0.029	0.029

Notes: AIC is Akaike Information Criterion. *BIC* is Bayesian Information Criterion. $RMSE^j$ is the root mean squared error for *j*-sector's share equation. Robust standard errors are in parentheses.

TABLE A3—EXCLUDING GOVERNMENT CONSUMPTION: ESTIMATION RESULTS

	1 (1)	2 (2)	3 (3)	4a (4)	4b (5)
σ	0.275	0.00131	0.00286	0.00615	
	(0.0441)	(0.00118)	(0.00191)	(0.00272)	
$\bar{c}^a$	−155.1	−163.1	−153.5	−121.3	−121.1
	(3.176)	(3.394)	(3.356)	(11.66)	(11.58)
$\bar{c}^s$		4,478.6		4,136.5	4,127.0
		(308.8)		(235.0)	(192.4)
$\bar{c}^{sh}$			−2,144.5	−4,694.7	−4,706.2
			(196.5)	(174.7)	(141.8)
ω^a	0.0000147	0.0000134	0.00000766	0.00245	0.00243
	(0.0000181)	(0.0000259)	(0.0000138)	(0.00111)	(0.00112)
ω^m	0.164	0.134	0.198	0.154	0.155
	(0.00362)	(0.00308)	(0.00288)	(0.00308)	(0.00299)
ω^s	0.836	0.866	0.802	0.843	0.843
	(0.00361)	(0.00309)	(0.00288)	(0.00342)	(0.00373)
ψ	0.527	0.531	0.553	0.596	0.596
	(0.00244)	(0.00300)	(0.00345)	(0.00462)	(0.00331)
Observations	64	64	64	64	64
AIC	−1,210.6	−1,212.8	−1,208.5	−1,330.3	−1,332.1
BIC	−1,179.1	−1,174.9	−1,170.6	−1,286.0	−1,294.2
$RMSE^a$	0.004	0.005	0.004	0.004	0.004
$RMSE^m$	0.010	0.009	0.011	0.006	0.006
$RMSE^{sm}$	0.061	0.053	0.046	0.027	0.027
$RMSE^{sh}$	0.057	0.064	0.042	0.032	0.032

Notes: AIC is Akaike Information Criterion. *BIC* is Bayesian Information Criterion. $RMSE^j$ is the root mean squared error for *j*-sector's share equation. Robust standard errors are in parentheses.

APPENDIX B: DERIVATION OF SECTORAL SHARE EQUATIONS

A. *Benchmark Case*

The Lagrangian for household's maximization problem (P3) is written as:

$$= \left(\sum_{i=a,m,s} \left(\omega^i\right)^{\frac{1}{\sigma}} \left(c_t^i + \bar{c}^i\right)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

$$+ \lambda_t \left[E_t - p_t^a c_t^a - p_t^m c_t^m - p_t^{sm} c_t^{sm} - p_t^{sh} c_t^{sh}\right],$$

where

$$c_t^s = \left[\psi \left(c_t^{sm}\right)^{\frac{\gamma-1}{\gamma}} + (1-\psi)\left(c_t^{sh} + \bar{c}^{sh}\right)^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}.$$

The first-order conditions are:

$$\frac{\partial}{\partial c_t^a} = 0 \Rightarrow (\omega^a)^{1/\sigma}(c_t^a + \bar{c}^a)^{\frac{-1}{\sigma}}(\Psi_t)^{\frac{1}{\sigma-1}} = \lambda_t p_t^a,$$

$$\frac{\partial}{\partial c_t^m} = 0 \Rightarrow (\omega^m)^{1/\sigma}(c_t^m + \bar{c}^m)^{\frac{-1}{\sigma}}(\Psi_t)^{\frac{1}{\sigma-1}} = \lambda_t p_t^m,$$

$$\frac{\partial}{\partial c_t^{sm}} = 0 \Rightarrow (\omega^s)^{1/\sigma}\psi(c_t^{sm})^{\frac{-1}{\gamma}}(c_t^s)^{\frac{1}{\gamma}}(c_t^s + \bar{c}^s)^{\frac{-1}{\sigma}}(\Psi_t)^{\frac{1}{\sigma-1}} = \lambda_t p_t^{sm},$$

$$\frac{\partial}{\partial c_t^{sh}} = 0 \Rightarrow (\omega^s)^{1/\sigma}(1-\psi)(c_t^{sh} + \bar{c}^{sh})^{\frac{-1}{\gamma}}(c_t^s)^{\frac{1}{\gamma}}(c_t^s + \bar{c}^s)^{\frac{-1}{\sigma}}(\Psi_t)^{\frac{1}{\sigma-1}} = \lambda_t p_t^{sh},$$

where

$$\Psi_t \equiv (\omega^a)^{1/\sigma}(c_t^a + \bar{c}^a)^{\frac{\sigma-1}{\sigma}} + (\omega^m)^{1/\sigma}(c_t^m + \bar{c}^m)^{\frac{\sigma-1}{\sigma}} + (\omega^s)^{1/\sigma}(c_t^s + \bar{c}^s)^{\frac{\sigma-1}{\sigma}}.$$

From the first-order conditions, we can derive the following share equations:

$$\frac{p_t^a c_t^a}{E_t} = f_1 \equiv \frac{(p_t^a)^{1-\sigma}\omega^a \Phi_{t,1}}{\Phi_{t,2}} - \frac{p_t^a \bar{c}_t^a}{E_t}, \tag{7}$$

$$\frac{p_t^m c_t^m}{E_t} = f_2 \equiv \frac{(p_t^m)^{1-\sigma}\omega^m \Phi_{t,1}}{\Phi_{t,2}} - \frac{p_t^m \bar{c}_t^m}{E_t}, \tag{8}$$

$$\frac{p_t^{sm} c_t^{sm}}{E_t} = f_3 \equiv \frac{(p_t^{sm})^{1-\sigma}\omega^s \psi^\sigma \Omega_{t,1}^{\frac{\sigma}{\gamma}-1}\Phi_{t,1}}{\Phi_{t,2}} - \frac{p_t^{sm}\Omega_{t,1}^{-1}\bar{c}^s}{E_t}, \tag{9}$$

where

$$\Phi_{t,1} \equiv \left(1 + \frac{p_t^a\bar{c}^a + p_t^m\bar{c}^m + p_t^{sh}\bar{c}^{sh} + p_t^{sm}\Omega_{t,1}^{-1}\bar{c}^s + p_t^{sh}\Omega_{t,2}^{-1}\bar{c}^s}{E}\right),$$

$$\Phi_{t,2} \equiv (p_t^a)^{1-\sigma}\omega^a + (p_t^m)^{1-\sigma}\omega^m + (p_t^{sm})^{1-\sigma}\omega^s\psi^\sigma\Omega_{t,1}^{\frac{\sigma}{\gamma}-1} + (p_t^{sh})^{1-\sigma}\omega^s(1-\psi)^\sigma\Omega_{t,2}^{\frac{\sigma}{\gamma}-1},$$

and where

$$\Omega_{t,1} \equiv \left[\psi + (1-\psi)\left(\frac{1-\psi}{\psi}\right)^{\gamma-1}\left(\frac{p_t^{sm}}{p_t^{sh}}\right)^{\gamma-1}\right]^{\frac{\gamma}{\gamma-1}},$$

$$\Omega_{t,2} \equiv \left[\psi\left(\frac{\psi}{1-\psi}\right)^{\gamma-1}\left(\frac{p_t^{sh}}{p_t^{sm}}\right)^{\gamma-1} + (1-\psi)\right]^{\frac{\gamma}{\gamma-1}}.$$

The share equations, (7), (8), and (9) are used for estimation.

B. *Disaggregated Case*

The Lagrangian for household problem is

$$= \left(\sum_{i=a,m,s} \left(\omega^i\right)^{\frac{1}{\sigma}} \left(c_t^i + \bar{c}^i\right)^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$$

$$+ \lambda_t \left[E_t - p_t^a c_t^a - p_t^m c_t^m - p_t^{sn} c_t^{sn} - p_t^{sm} c_t^{sm} - p_t^{sh} c_t^{sh}\right],$$

where

$$c_t^s = \left[\phi\left(c_t^{sn}\right)^{\frac{\rho-1}{\rho}} + (1-\phi)\left(c_t^{sc} + \bar{c}^{sc}\right)^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}},$$

and

$$c_t^{sc} = \left[\psi\left(c_t^{sm}\right)^{\frac{\gamma-1}{\gamma}} + (1-\psi)\left(c_t^{sh} + \bar{c}^{sh}\right)^{\frac{\gamma-1}{\gamma}}\right]^{\frac{\gamma}{\gamma-1}}.$$

From FOCs we can derive the share equations,

$$\frac{p_t^a c_t^a}{E_t} = g_1 \equiv \frac{\left(p_t^a\right)^{1-\sigma} \omega^a \chi_{t,1}}{\chi_{t,2}} - \frac{p_t^a \bar{c}^a}{E_t},$$

$$\frac{p_t^m c_t^m}{E_t} = g_2 \equiv \frac{\left(p_t^m\right)^{1-\sigma} \omega^m \chi_{t,1}}{\chi_{t,2}} - \frac{p_t^m \bar{c}^m}{E_t},$$

$$\frac{p_t^{sn} c_t^{sn}}{E_t} = g_3 \equiv \frac{\left(p_t^{sn}\right)^{1-\sigma} \omega^s \phi^\sigma \left(\Lambda_{t,1}\right)^{\frac{\sigma}{\rho}-1} \chi_{t,1}}{\chi_{t,2}} - \frac{p_t^{sn}\left(\bar{c}^{sn} + \Lambda_{t,1}^{-1} \bar{c}^s\right)}{E_t},$$

$$\frac{p_t^{sm} c_t^{sm}}{E_t} = g_4 \equiv \frac{\left(p_t^{sm}\right)^{1-\sigma} \omega^s \psi^\sigma \left(\Gamma_{t,1}\right)^{\frac{\sigma}{\gamma}-1} (1-\phi)^\sigma \left(\Lambda_{t,2}\right)^{\frac{\sigma}{\rho}-1} \chi_{t,1}}{\chi_{t,2}}$$

$$- \frac{p_t^{sm}\left(\Gamma_{t,1}^{-1} \bar{c}^{sc} + \Gamma_{t,1}^{-1} \Lambda_{t,2}^{-1} \bar{c}^s\right)}{E_t},$$

where

$$\Gamma_{t,1} \equiv \left[\psi + (1-\psi)\left(\frac{1-\psi}{\psi}\right)^{\gamma-1} \left(\frac{p_t^{sm}}{p_t^{sh}}\right)^{\gamma-1}\right]^{\frac{\gamma}{\gamma-1}},$$

$$\Gamma_{t,2} \equiv \left[\psi\left(\frac{\psi}{1-\psi}\right)^{\gamma-1} \left(\frac{p_t^{sh}}{p_t^{sm}}\right)^{\gamma-1} + (1-\psi)\right]^{\frac{\gamma}{\gamma-1}},$$

$$\Lambda_{t,1} \equiv \left[\phi + (1-\phi)\left(\frac{1-\phi}{\phi}\right)^{\rho-1}\left(\frac{p_t^{sn}}{p_t^{sm}}\right)^{\rho-1}\left(\psi \Gamma_{t,1}^{\frac{1}{\gamma}}\right)^{\rho-1}\right]^{\frac{\rho}{\rho-1}},$$

$$\Lambda_{t,2} \equiv \left[\phi\left(\frac{\phi}{1-\phi}\right)^{\rho-1}\left(\frac{p_t^{sm}}{p_t^{sn}}\right)^{\rho-1}\left(\psi \Gamma_{t,1}^{\frac{1}{\gamma}}\right)^{1-\rho} + (1-\phi)\right]^{\frac{\rho}{\rho-1}},$$

and where

$$\chi_{t,1} \equiv \left(1 + \frac{p_t^a \bar{c}^a + p_t^m \bar{c}^m + p_t^{sn}\Lambda_{t,1}^{-1}\bar{c}^s + p_t^{sm}\Gamma_{t,1}^{-1}\bar{c}^{sc} + p_t^{sm}\Gamma_{t,1}^{-1}\Lambda_{t,2}^{-1}\bar{c}^s + p_t^{sh}\bar{c}^{sh} + p_t^{sh}\Gamma_{t,2}^{-1}\bar{c}^{sc} + p_t^{sh}\Gamma_{t,2}^{-1}\Lambda_{t,2}^{-1}\bar{c}^s}{E_t}\right),$$

$$\chi_{t,2} \equiv (p_t^a)^{1-\sigma}\omega^a + (p_t^m)^{1-\sigma}\omega^m + (p_t^{sn})^{1-\sigma}\omega^s\phi^\sigma(\Lambda_{t,1})^{\frac{\sigma}{\rho}-1}$$
$$+ (p_t^{sm})^{1-\sigma}\omega^s\psi^\sigma(\Gamma_{t,1})^{\frac{\sigma}{\gamma}-1}(1-\phi)^\sigma(\Lambda_{t,2})^{\frac{\sigma}{\rho}-1}$$
$$+ (p_t^{sh})^{1-\sigma}\omega^s(1-\psi)^\sigma(\Gamma_{t,2})^{\frac{\sigma}{\gamma}-1}(1-\phi)^\sigma(\Lambda_{t,2})^{\frac{\sigma}{\rho}-1}.$$

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