Two Perspectives on Preferences and Structural Transformation[*]

By Berthold Herrendorf, Richard Rogerson, and Ákos Valentinyi

We assess the empirical importance of changes in income and relative prices for structural transformation in the postwar US. We explain two natural approaches to the data: sectors may be categories of final expenditure or value added; e.g., the service sector may be the final expenditure on services or the value added from service industries. We estimate preferences for each approach and find that with final expenditure income effects are the dominant force behind structural transformation whereas with value added categories price effects are more important. We show how the input–output structure of the US can reconcile these findings.
JEL: O11; O14
Keywords: income effects; preferences; relative price effects; structural transformation

Structural transformation – i.e., the reallocation of resources across the broad economic sectors agriculture, manufacturing, and services – is a prominent feature of economic development. Kuznets (1966) included it as one of the main stylized facts of development, and recent work shows that extending the standard one–sector growth model to incorporate structural transformation is important for a variety of substantive issues.[1] However, there remains no consensus on the economic forces that drive the process of structural transformation. Recent theories stress two distinct economic mechanisms that can explain why households reallocate expenditures across broad economic sectors: one

emphasizes changes in aggregate income, whereas the other emphasizes changes in relative sectoral prices. For example, Kongsamut, Rebelo and Xie (2001) assume that only income changes matter, whereas Baumol (1967) and Ngai and Pissarides (2007) assume that only relative price changes matter. In the data, both income and relative prices have changed significantly. We ask: How important is each of these changes as a source of structural transformation?[2]

In addition to being crucial for understanding the driving forces behind structural transformation, the answer to this question has important implications. For example, the decline of the manufacturing sector figures prominently in public policy discussions, and a recurring issue is what public policies could slow or even reverse it. This depends crucially on the forces that lead to the decline, and in particular on the relative strengths and on the directions of income and price effects. Another example where the answer to this question has important implications is the future path of economic growth. In a classic contribution, Baumol (1967) suggested that the secular increase in the expenditures on many labor–intensive services is largely due to an increase in their relative prices, reflecting the fact that there is little technological progress in labor–intensive services. This so–called Baumol disease is of concern because it slows down growth of real aggregate GDP. The extent to which this happens critically depends on the nature of income and price effects. On the one hand, if the income elasticity of services is larger than one and if services are complements to the other consumption goods, then the economy is continually reallocating economic activity towards a sector with low productivity growth. On the other hand, if the income elasticity of services is smaller than one and if services are substitutes to the other consumption goods, then the economy is continually reallocating economic activity away from a sector with low productivity growth.

We seek to assess the relative importance of changes in income and in relative prices as driving forces for structural transformation in the US economy over the period 1947–2010. Because these two mechanisms ultimately reflect different features of preferences, our objective amounts to answering the question: What is an empirically reasonable specification of preferences in models of structural transformation?[3] In answering this question, our analysis offers three contributions.

First, we point out a fundamental ambiguity regarding the conceptual definition of commodities that arises when one seeks to connect a multi–sector model to the data. To see the ambiguity, consider a static stand–in household model with utility function $u(c_a, c_m, c_s)$, where c_a, c_m and c_s are consumption of agriculture, manufacturing and services, respectively, and three sectoral production functions, $c_i = f^i(h_i)$ for $i = a, m, s$ where h denotes labor input. Even conditional on giving specific labels to the sectors, there are still two very different interpretations of what a sector is. If one interprets the sectoral production functions as value added production functions, consistency dictates

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[2]We will refer to these effects as income effects and price effects. Our terminology differs somewhat from that in microeconomics where the effects of changes in relative prices are decomposed into income and substitution effects. In our terminology, the price effect comprises both the income and substitution effect of this decomposition whereas the income effect is the result of any change in income.

[3]A companion paper, Herrendorf, Herrington and Valentinyi (2012), focuses on the related question, What is an empirically reasonable specification for sectoral technology in models of structural transformation?

that the arguments of the utility functions are necessarily the value added components of final consumption. We will call this the consumption value added approach. To illustrate the significance of this observation, consider the example of a cotton shirt. With the value added interpretation, a cotton shirt represents consumption of all three commodities: raw cotton from agriculture, processing from manufacturing, and retail services from services sector.

Alternatively, one could interpret the commodities in the utility function as the final consumption purchases of the household. In this case the entire expenditure on the cotton shirt represents consumption of manufactured goods, while a service such as health care, for example, would be entirely counted as consumption of services. We call this the final consumption expenditure approach. Consistency now requires that the sectoral production functions be final consumption production functions rather than value added production functions. Each of these two approaches is internally consistent, but for a given model, the empirically reasonable choices for the parameters of utility and production functions will potentially differ.

A separate questions is whether one of these specifications is more reasonable. Following Lancaster (1966), a reasonable starting position is that households value a large set of characteristics that are bundled in various combinations in different goods. The two approaches we describe reflect two different attempts to "aggregate" these preferences using a utility function with a small set of arguments. Any attempt to capture this complex ordering using a utility function with few arguments will lead to some undesirable implications in specific contexts. For example, it may seem undesirable that the value added approach implies that individuals worry about the intermediate inputs that go into the production of a given final good (though we note that there certainly are examples for which this is the case, such as organic vegetables or canned tuna that is produced using methods that do not endanger dolphins). But, it as undesirable that in the final expenditure approach the utility that one obtains from eating an apple is bundled with the services that are offered at the supermarket where the apple is bought, as opposed to separately considering utility from the apple and utility from the services offered at the supermarket. We think that the point here is not that one approach is better, but that any specification that aggregates underlying characteristics into a small number of categories is going to have its individual strengths and weaknesses in terms of capturing relevant aspects of preferences.

Our second contribution is to estimate utility functions for each of these two approaches and assess their implications for the driving forces behind structural transformation.[4] In each case we find that a relatively simple utility function provides a good fit to the relevant data. Importantly, the two specifications have fundamentally different properties, thereby emphasizing the empirical significance of the ambiguity noted above. For the final consumption expenditure approach, a specification close to the Stone–Geary

[4]Whereas the relevant data for the final expenditure approach is readily available, this is not true for the consumption value added approach. To be sure, data on total value added by sector are readily available, but these data are not sufficient because not all of total value added is consumed. One of the by–products of this paper is to lay out and implement a procedure for extracting the consumption component of total value added, and to produce an annual time series for U.S. consumption value added by sector between 1947 and 2010.

utility function provides a good fit to these data, implying that changes in income rather than changes in relative prices are the dominant force behind changes in expenditure shares. For the consumption value added approach, changes in income are much less important and changes in relative prices are much more important than for final expenditure. In particular, a specification close to a Leontief utility function now provides a good fit to the data. In other words, our findings provide some measure of support for each of the specifications emphasized by Kongsamut, Rebelo and Xie (2001) and Ngai and Pissarides (2007), with the appropriate choice being dictated by how one interprets the arguments in the utility function: under the final consumption expenditure approach, the Stone–Geary specification of Kongsamut, Rebelo and Xie (2001) is a reasonable approximation, whereas under the consumption value added approach, the homothetic specification of Ngai and Pissarides (2007) is a reasonable approximation.

We emphasize that our two estimated utility functions are based on two different representations of the same underlying data. In particular, the final consumption expenditure data are linked to the consumption value added data through intricate input–output relationships, which implicitly translate part of the income effects that dominate with final consumption expenditure into relative price effects that are much more important with consumption value added, and vice versa. Our third contribution is to explore how the input–output structure influences the mapping between the two different representations and to derive conditions under which a specification close to Stone–Geary for final consumption expenditure is consistent with a specification close to Leontief representation for consumption value added.

While our analysis is motivated by a desire to build empirically reasonable models of structural transformation, some of our basic messages are relevant for any applied analysis in the context of multi–sector models. Specifically, researchers must be careful to apply consistent definitions of commodities on both the household and production sides when connecting multi–sector models with data. Changing what is meant by the label "services", for example, has implications not only on the household side for what form of utility function is appropriate, but also on the production side for such things as the measurement of productivity growth. This has important implications for comparing results across studies and for the practice of importing parameter values across studies. For example, it is not appropriate in general to use the utility function that was estimated from final consumption expenditure together with value added production functions at the sector level. If one wants to use a utility function that was estimated from final consumption expenditure, then one either needs to write down a production structure that captures the complexities of the input–output relationships at the sector level, or find a representation of production that isolates the contribution of capital and labor to the production of final expenditure categories. While this can be done, it is much more difficult than working directly with sectoral value added production functions.[5]

An outline of the paper follows. In the next section we describe the model and the method that we use to calibrate preference parameters. In Section II we describe the final

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[5]Valentinyi and Herrendorf (2008) showed how to construct sectoral production functions that use only capital and labor to produce final expenditure by broad category.

consumption expenditure method and we report the estimation results for this method. In Section III, we turn to consumption value added. We explain in some detail how to construct the relevant time series of variables from existing data and we report the estimation results. Section IV links the results of both methods and provides intuition for the differences. Moreover, it discusses the relative merits of the two methods and some additional measurement issues. Section V concludes.

I. Model

As noted in the introduction, our objective is to determine what form of preferences for a stand–in household defined over broad categories are consistent with U.S. data for expenditure shares since 1947. This section develops the model that we use to answer this question.

We consider an infinitely lived household with preferences represented by a utility function of the form:

$$\sum_{t=0}^{\infty} \beta^t \frac{u(c_{at}, c_{mt}, c_{st})^{1-\rho} - 1}{1 - \rho},$$

where $\rho > 0$ is the intertemporal elasticity of substitution of consumption and the indices a, m, and s refer to the three broad sectors of agriculture, manufacturing, and services.[6] We could generalize this utility function and introduce leisure. This would not change our results if the generalized utility function was separable between consumption and leisure so that the utility of leisure did not influence the optimal allocation of expenditures across consumption categories for given prices and total expenditure.

We further assume that the period utility function $u(c_{at}, c_{mt}, c_{st})$ is of the form:

(1)
$$u(c_{at}, c_{mt}, c_{st}) = \left(\sum_{i=a,m,s} \omega_i^{\frac{1}{\sigma}} (c_{it} + \bar{c}_i)^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}},$$

where ω_i are non–negative weights that add up to one and $\bar{c}_i$ are constants. We restrict $\bar{c}_m$ to be zero but allow $\bar{c}_a$ and $\bar{c}_s$ to take any value.[7] If the $\bar{c}_i$'s are all zero, then preferences are homothetic and $\sigma > 0$ is the within–period elasticity of substitution between consumption categories.

This is the most parsimonious utility specification that nests the specifications used by Kongsamut, Rebelo and Xie (2001) and Ngai and Pissarides (2007). The preferences used by Kongsamut et al are the special case in which $\sigma = 1$, $\bar{c}_a < 0$ and $\bar{c}_s > 0$. The

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[6]The exact definition of these sectors for each of the two specifications that we consider will be provided later. We note here that we have followed the convention of using the label "manufacturing" to describe a sector which consists of manufacturing and some other sectors (e.g., mining and construction). While the label "industry" is perhaps more appropriate to describe this sector, we will later use the term "industry" to describe a generic production activity and the index i to denote a generic sector. In view of this, "manufacturing" seems a better choice.

[7]We have experimented with an unrestricted specification where $\bar{c}_m$ could take any value but found that the goodness of fit hardly changed. As a result we follow Kongsamut, Rebelo and Xie (2001) in restricting $\bar{c}_m$ to equal zero.

implied utility function was first introduced by Stone (1954) and Geary (1950-1951):[8]

(2) $u(c_{at}, c_{mt}, c_{st}) = \omega_a \log(c_{at} + \bar{c}_a) + \omega_m \log(c_{mt}) + \omega_s \log(c_{st} + \bar{c}_s).$

The preferences used by Ngai and Pissarides are the special case in which $\sigma < 1$ and $\bar{c}_a = \bar{c}_s = 0$. This is a homothetic CES specification with less substitutability than log:

(3) $$u(c_{at}, c_{mt}, c_{st}) = \left(\sum_{i=a,m,s} \omega_i^{\frac{1}{\sigma}} c_{it}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}.$$

Two remarks are at order. First, we assumed that the elasticity parameter σ is the same among all three consumption categories. While this may seem somewhat restrictive, it is important to realize that if the non–homotheticity terms are different from zero, then σ is *not* equal to the elasticity of substitution between consumption categories. In other words, our specification does allow for differences in the elasticity of substitution between different pairs of consumption categories. Second, if all households have preferences of the above form and have total consumption expenditure that exceed a minimum level, then aggregate expenditures are consistent with those for a stand–in household with preferences of the same form. The precise condition is in the Online Appendix A where we derive this result formally. This property extends to settings in which individuals make consumption–savings decisions if there are complete markets.

Consider the stand–in household in a setting in which it maximizes lifetime utility given a market structure that features markets for each of the three consumptions and a market for borrowing and lending at each date t. Our strategy is to focus solely on the implications for optimal consumption behavior within each period. The advantage of this "partial" approach is that we do not have to take a stand on the exact nature of intertemporal opportunities available to the household (i.e., the appropriate interest rates for borrowing and lending), or to specify how expectations of the future are formed. With these assumptions, if C_t is observed total expenditure on consumption in period t and p_{it} are observed prices, then it follows that the consumption choices in period t must solve the following static optimization problem:

$$\max_{c_{at}, c_{mt}, c_{st}} u(c_{at}, c_{mt}, c_{st}) \quad \text{s.t.} \quad \sum_{i=a,m,s} p_{it} c_{it} = C_t.$$

Assuming interior solutions, the first–order conditions for the above maximization problem are easily derived.[9] Some simple algebra yields the following expression for the

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[8]The implied demand model is often called the Linear Expenditure System. Deaton and Muellbauer (1980) is another classic contribution to the literature on expenditure systems.

[9]In general, of course, the nonhomotheticity terms in our class of utility functions can lead to corner solutions. However, this is not relevant for *aggregate* consumption in a *rich* country such as the postwar U.S. Looking ahead, we will find that the stand–in household chooses quantities that are far away from corners.

expenditure shares:

$$(4) \qquad s_{it} \equiv \frac{p_{it}c_{it}}{C_t} = \frac{\omega_i p_{it}^{1-\sigma}}{\sum_{j=a,m,s} \omega_j p_{jt}^{1-\sigma}} \left(1 + \sum_{j=a,m,s} \frac{p_{jt}\bar{c}_j}{C_t} \right) - \frac{p_{it}\bar{c}_i}{C_t}.$$

In the empirical work reported below, we will estimate the parameters of the utility function using (4).

II. Final Consumption Expenditure

The final consumption expenditure method originated in the literature on expenditure systems and associates the arguments of the utility function with final expenditure of households over different categories of goods and services. Specifically, this method classifies the expenditures on individual *commodities* into the three broad sectors agriculture, manufacturing, and services. For example, purchases of food from supermarkets will be included in c_{at}, purchases of clothing will be included in c_{mt}, and purchases of air–travel services will be included in c_{st}.

A. *Implementing the Final Consumption Expenditure Specification*

The required data in this case are total consumption expenditure and the expenditure shares and prices for final consumption expenditure on different commodities. These data are readily available from the BEA.[10]

While expenditure shares do not depend on how one splits total expenditures into their price and quantity components, the series for prices do. That is, given total expenditure, different procedures for inferring the consumption quantities will imply different relative prices. Consistent with BEA measurement, we measure final consumption quantities using chain–weighted indices. For the period 1947–2010 and for the available commodities, we obtain annual data on final consumption expenditure, chain–weighted final consumption quantities, and chain–weighted prices from the BEA. Since quantities calculated with the chain–weighted method are not additive, we use the so called cyclical expansion procedure to aggregate quantities that are not available from the BEA.[11] We assign each commodity to one of the three broad sectors agriculture, manufacturing, and services. A detailed description of this assignment can be found in the Online Appendix A.2. Note that for estimating utility function parameters we do not need to know whether the commodities purchased by the household are produced in the U.S. economy or imported. All that matters for our exercise is information on total consumption expenditure, expenditure shares and prices.

Figures 1–3 show the resulting evolution of the expenditure shares, prices and quantities, respectively. Looking at Figure 1, we see that the data are consistent with the stan-

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[10]Specifically, we use data from the National Income and Product Accounts, the Annual Industry Accounts, the Benchmark Input–Output Accounts, and the Fixed Asset Accounts. The exact data sources can be found in the Online Appendix A.1. and in the data files.

[11]See the Online Appendix C for the description of the cyclical expansion procedure. See Landefeld and Parker (1997) for the approximate aggregation, and Whelan (2002) for more discussion about chain–weighted indices.

Final Consumption Expenditure Per Capita

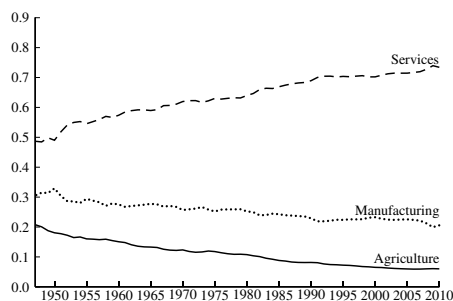FIGURE 1. EXPENDITURE SHARES FIGURE 2. PRICE INDICES (1947=1)
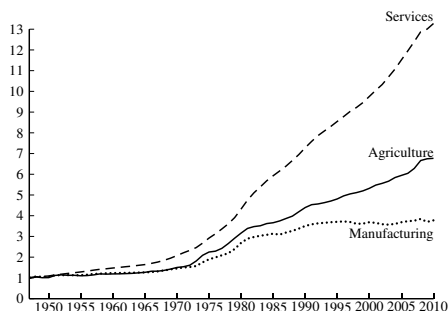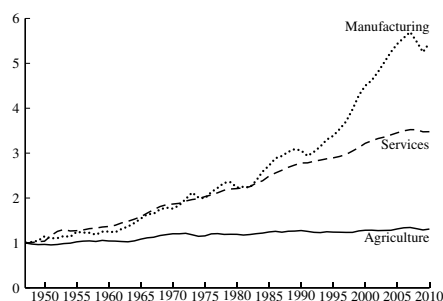

FIGURE 3. QUANTITY INDICES (2005 CHAINED DOLLARS, 1947=1)

dard (asymptotic) pattern of structural transformation: The expenditure share for services is increasing, while those for agriculture and manufacturing are decreasing. Turning next to Figure 2, which shows the evolution of prices (with prices in 1947 normalized to 1), we see that while all three prices have increased, the price of services has increased relative to both manufacturing and agriculture and the price of agriculture has increased relative to manufacturing. Figure 3 shows real quantities relative to their 1947 values. Here we see that while the quantities of all three categories have increased, the quantity of manufacturing has grown the most, while the quantity of agriculture has grown the least.

Figures 1–3 already suggest some of the qualitative features of the utility specification that our estimation will select. First, note that the price of services has increased relative to that of agriculture, while at the same time the quantity of services has also increased relative to that of agriculture. This is qualitatively inconsistent with a homothetic utility specification, which would have relative prices and relative quantities move in opposite directions. In the context of our class of utility functions, reconciling these observations amounts to having $\bar{c}_a < 0$ and/or $\bar{c}_s > 0$. Second, as the price of agriculture relative to manufacturing has increased, the quantity of agriculture relative to manufacturing has decreased. This is consistent with there being substitutability between agriculture and manufacturing. While to some extent this could also be accounted for by having $\bar{c}_a < 0$, in the context of our preference specification, it turns out that σ will come out close to one.

B. Results with Final Consumption Expenditure

In this section we estimate the parameters of the demand system (4) by using iterated feasible generalized nonlinear least square estimation. This is a fairly standard way of estimating demand systems; see Deaton (1986).[12] Since the expenditure shares sum to one, the error covariance matrix is singular. Therefore we drop the demand for agricultural goods when we do the estimation. Note that the estimation results are not affected by which equation we drop. To deal with the issue that four out of our six parameters are constrained (i.e., $\sigma \geq 0$, $\omega_i \geq 0$, and $\omega_a + \omega_m + \omega_s = 1$) we transform the constrained parameters into unconstrained parameters as follows:

$$\sigma = e^{b_0}, \quad \omega_a = \frac{1}{1 + e^{b_1} + e^{b_2}}, \quad \omega_m = \frac{e^{b_1}}{1 + e^{b_1} + e^{b_2}}, \quad \omega_m = \frac{e^{b_2}}{1 + e^{b_1} + e^{b_2}},$$

where $b_0, b_1, b_2 \in (-\infty, +\infty)$. We estimate the model in terms of the unconstrained parameters b_0, b_1, b_2 and $\bar{c}_a, \bar{c}_s$ and then calculate the point estimates and standard errors of the constrained parameters $\sigma, \omega_a, \omega_m, \omega_s$.

Table 1 shows the results for three different specifications. For now we focus on the first two columns; the estimates from the third column are discussed in the next subsection. Column (1) shows the results when we do not impose any restrictions on the parameters. The point estimate for σ is 0.85 and the signs of the two unrestricted non-homothetic terms have the pattern suggested by Kongsamut, Rebelo and Xie (2001), that is, $\bar{c}_a < 0$ and $\bar{c}_s > 0$. Figure 4 shows that the fit of the estimated model from Column (1) to the data on final consumption expenditure shares is very good.

While the specification from Column (1) is similar to the Stone–Geary specification imposed by Kongsamut, Rebelo and Xie (2001), it is not identical, since Stone–Geary assumed that $\sigma = 1$. To assess the extent to which this specification fits the data, Column (2) shows estimates when we impose $\sigma = 1$. The nonhomothetic terms retain the same sign configuration, although the magnitude of $\bar{c}_s$ increases significantly. This is intuitive: a higher σ implies that households respond to the given increase in the relative price of services by substituting away from services, and the higher value of $\bar{c}_s$ serves to offset this response. Figure 5 shows that the specification of Column (2) fits virtually as well as the specification of Column (1). This is consistent with the fact that in Table 1 the Akaike information criterion (AIC) and the root mean square errors for each of the three expenditure share series hardly change.[13]

The chi–squared statistics reported in the table show that we can reject the hypothesis

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[12]More precisely, our demand system falls into the non–linear seemingly unrelated regression framework. The equations seem "unrelated" because the endogenous variables do not feature as explanatory variables in other equations; but in general they are related through the covariance structure of the error terms. Assuming that the error terms are not correlated with the exogenous variables, iterating on the feasible generalized nonlinear least square estimator produces a sequence of parameter estimates that converges to the maximum likelihood estimates; see Greene (2011, Chapter 14.9.3). For further discussion on the econometric issues related to the estimation of demand systems, see the review article by Barnett and Serletis (2008).

[13]We do not report the standard R^2 statistic here because it is not well defined for non–linear regressions. Instead, we report the Akaike information criterion and the root mean squared errors. Note that to judge the goodness of fit, one needs to consider the change in the level of the Akaike information criterion across specifications; the level itself provides no information. If the measure increases by Δ as we go from one specification to another, then the likelihood of the latter

TABLE 1—RESULTS WITH FINAL CONSUMPTION EXPENDITURE

	(1)	(2)	(3)
σ	0.85**	1	0.89**
	(0.06)	–	(0.02)
$\bar{c}_a$	−1350.38**	−1315.99**	
	(31.18)	(26.48)	
$\bar{c}_s$	11237.40**	19748.22**	
	(2840.77)	(1275.69)	
ω_a	0.02**	0.02**	0.11**
	(0.001)	(0.001)	(0.005)
ω_m	0.17**	0.15**	0.24**
	(0.01)	(0.004)	(0.00)
ω_s	0.81**	0.84**	0.65**
	(0.01)	(0.005)	(0.01)
$\chi^2(\bar{c}_a = 0, \bar{c}_s = 0)$	3866.73**	4065.33**	
AIC	−932.55	−931.35	−666.03
$RMSE_a$	0.004	0.004	0.040
$RMSE_m$	0.009	0.009	0.022
$RMSE_S$	0.010	0.011	0.061

Robust standard errors in parentheses * $p < 0.05$, ** $p < 0.01$

χ^2 is the Wald Test Statistics for the hypothesis that $\bar{c}_a$ and $\bar{c}_s = 0$ are jointly zero.
AIC is the Akaike information criterion, $RMSE_i$ is the root mean squared error for equation i.

TABLE 2—NONHOMOTHETICITY TERMS RELATIVE TO FINAL CONSUMPTIONEXPENDITURE FROM THE DATA

	1947	2010
$-p_a\bar{c}_a/C$	0.17	0.04
$p_s\bar{c}_s/C$	0.73	0.32
$-\bar{c}_a/c_a$	0.81	0.62
$\bar{c}_s/c_s$	1.49	0.43

Fit of Expenditure Shares with Final Consumption Expenditure

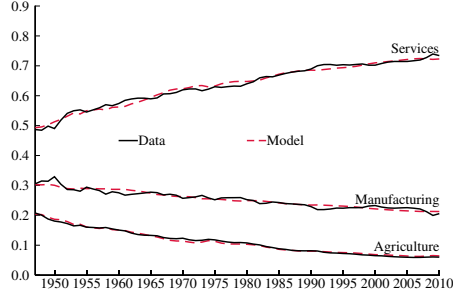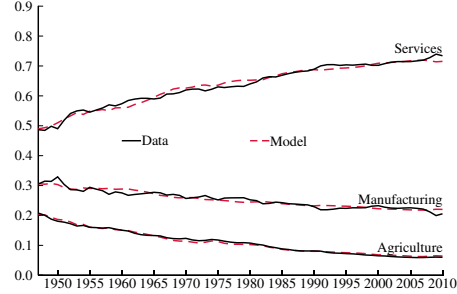FIGURE 4. FIT OF COLUMN (1)   FIGURE 5. FIT OF COLUMN (2)

that both non–homotheticity terms are equal to zero. We have also considered specifica-tions where one of these terms is set to zero. In the interests of space we do not report the full set of results, but we note that setting $\bar{c}_a$ results in a large increase in both the AIC and the root mean square errors, whereas the increase is much smaller when we set $\bar{c}_s = 0$. We conclude that the non–nonhomotheticity associated with $\bar{c}_a$ are empirically the most important.

We conclude that when using data on final consumption expenditure, the data broadly support the Stone–Geary specification of Kongsamut, Rebelo and Xie (2001).[14] Having said that, note that these authors also imposed the condition

$$p_{at}\bar{c}_a + p_{st}\bar{c}_s = 0,$$

which is required for the existence of a generalized balanced growth path in their model.[15] This condition is rather trivially not consistent with the final consumption expenditure data, since Figure 2 clearly shows that p_{st}/p_{at} has been steadily increasing since 1947 whereas $\bar{c}_a$ and $\bar{c}_s$ are constants.

At first pass it may appear problematic that the estimated specification is not consis-tent with balanced growth, since balanced growth is often viewed as a robust feature of the data. In fact, this issue turns out not to be quantitatively significant. Kongsamut, Rebelo and Xie (2001) includes simulation results for specifications that depart from the conditions required for exact balanced growth and show that the resulting time series are still very close to satisfying balanced growth. To the extent that the stylized fact is

relative to the former specification equals $exp(-\Delta/2)$. See Burnham and Anderson (2002) for a detailed treatment of the Akaike information criterion.

[14]Our results are related to some earlier work. For example, Pollak and Wales (1969) studied aggregate US data from 1948 to 1965 on food, clothing, shelter, and miscellaneous items and found that the linear expenditure system implied by a Stone–Geary utility function fits the data very well and that the nonhomotheticity terms are important. For a subsequent literature review, see Blundell (1988).

[15]Given the nonhomotheticity terms, their model does not have a balanced growth path in the usual sense of the word. They therefore consider a generalized balanced growth path, which they define as a growth path along which the real interest rate is constant.

simply that balanced growth is a good approximate description of the data, there is no inconsistency. Similar calculations also appear in Gollin, Parente and Rogerson (2006), who used a somewhat different commodity space though.

C.   Income versus Price Effects with Final Consumption Expenditure

In this subsection we take a closer look at the relative importance of changes in income and relative price in accounting for the observed changes in the shares of final consumption expenditures. As a first pass it is useful to provide some perspective on the size of the estimated nonhomotheticity terms in Column (1). Table 2 reports the value of the $\bar{c}_i$'s relative to several values from the data in the first and last years of our sample. Most notably, rows three and four show that in both 1947 and 2009, each of the nonhomotheticity terms are sizeable compared to the actual consumption quantities of agriculture and services, suggesting that income effects could play an important role in shaping the shares of final consumption expenditure.

To explore this issue further, Figure 6 shows the fit of the expenditure shares implied by the parameters of Column (1) under the counterfactual in which total expenditure change as dictated by the data but relative prices are held constant at their 1947 values. Although the fit deteriorates somewhat, this counterfactual still captures the vast majority of the changes in the expenditure shares. The main discrepancy between the data and the model are that the share of services now increases slightly more than in the data and the share of agriculture decreases slightly more than in the data. This discrepancy is intuitive since the price of services increases relative to agriculture during the sample period, and therefore works to partially offset the changes associated with these income effects. This is illustrated in Figure 7, which shows the fit of the expenditure shares implied by the parameters of Column (1) under the counterfactual in which prices change as dictated by the data but total expenditure are held constant at their 1947 values. We can see that price effects alone drive the expenditure shares in the opposite direction to income effects and to what is observed in the data.

A second way to judge the importance of income versus relative prices is to assess the extent to which a homothetic specification can fit the data, since such a specification necessarily implies that total expenditure has no effect on expenditure shares. Column (3) of Table 1 presents the estimates when the nonhomothetic terms are restricted to equal zero. The point estimate for the elasticity parameter σ increases from 0.85 to 0.89, but most importantly, the Akaike information criterion significantly increases, as do all of the root mean square errors, implying that the fit deteriorates considerably. Figure 8 confirms, showing that the fit becomes quite poor for agriculture relative to the previous two specifications. We conclude that the income effects associated with the nonhomotheticities are the dominant source of the observed structural transformation in the shares of final consumption expenditure.

III.   Consumption Value Added

As noted in the introduction, many multi–sector general equilibrium models represent the sectoral production functions in value added form, in which case the arguments of the

FIGURE 6. FIT OF COLUMN (1) WITH RELATIVE PRICES FIGURE 7. FIT OF COLUMN (1) WITH INCOME FIXED AT 1947
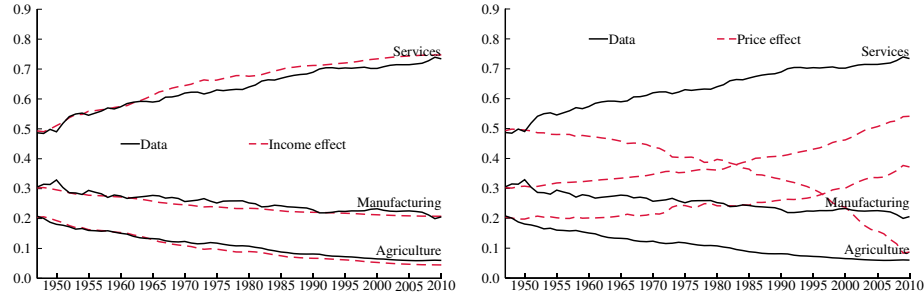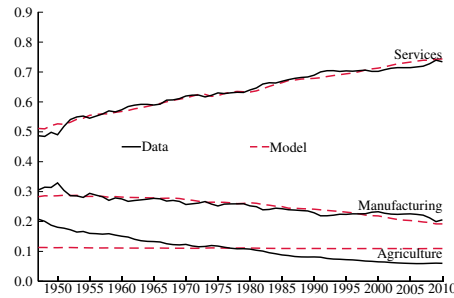
FIXED AT 1947 VALUES VALUES

FIGURE 8. FIT OF HOMOTHETIC SPECIFICATION IN COLUMN

(3)

utility function necessarily represent the value added components of final expenditure. Individual *industries* are then classified into different broad sectors, and a sector is a collection of industries, with sector value added being the sum of the value added of the industries belonging to it. Effectively, this way of proceeding breaks consumption spending into its value added components. For example, purchases from supermarkets will then be broken down into the components of c_{at} (food), c_{mt} (processing of the food) and c_{st} (distribution services). Similarly, purchases of clothing will be broken down into the components of c_{at} (raw materials, say cotton), c_{mt} (processing of cotton into clothing) and c_{st} (distribution services), and purchases of air–travel services will be broken down into the components of c_{mt} (fuel) and c_{st} (transportation services).

Note that the final–expenditure and the value–added specifications are two different representations of the same underlying data. The data on final consumption expenditure are linked to the data on consumption value added through complicated input–output relationships, and vice versa. We explore the mapping between these two specifications in more detail in a later section.

A. *Implementing the Consumption Value Added Specification*

In this section we describe how to construct the relevant data when one identifies the three consumption categories with their respective value added components. The exact data sources can be found in the Online Appendix A.1. Similar to the case of final expen-

Figure 9. Expenditure Shares   Figure 10. Price Indices (1947=1)
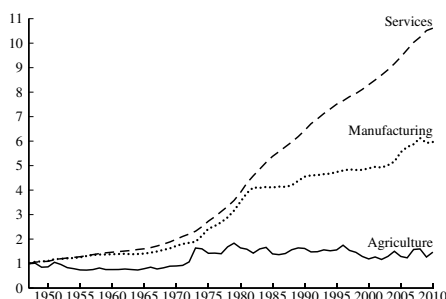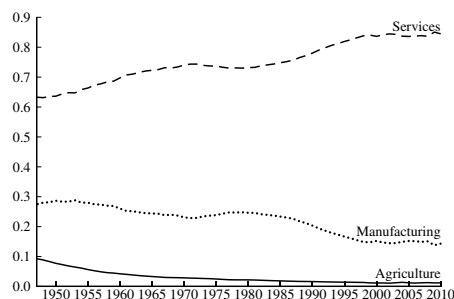

Figure 11. Quantity Indices (2005 chained dollars, 1947=1)
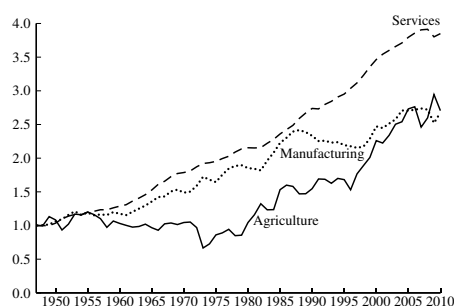
diture shares, there is annual data available from the BEA on value added by industry, as well as real value added and prices. As we mentioned above, the consumption value added method assigns industries, instead of commodities, to the three broad sectors. The Online Appendix A.2 describes the details of this assignment.

Although readily available, the data on value added and prices are not sufficient for our purposes. The reason is that value added data come from the production side of the national income and products accounts, and so contain both consumption and investment. It is therefore necessary to devise a method to extract the consumption component from the production value added of each sector. This has not been sufficiently appreciated in the literature, which often proceeds by assuming that all investment is done in manufacturing. This assumption is problematic, since from 1999 onward the BEA reports that the total value added in manufacturing has been consistently smaller than investment. We therefore need to properly extract the consumption component from the total value added in each sector. One contribution of our paper is to lay out a procedure that achieves this.

To carry out this extraction one needs to combine the value added data from the income side of the NIPA with the final expenditure data from the expenditure side of the NIPA. The complete details of this procedure are fairly involved, and so we relegate its description to the Online Appendix B.1. Here we provide a rough sketch. A key difference between value added data from the income side and final expenditure data from the expenditure side is that the former are measured in what the BEA calls *producer's prices* whereas the latter are measured in *purchaser's prices*. From a practical perspective, the key difference is that purchaser's prices include distribution costs whereas producer's

price do not (distribution costs are sales taxes and transport, wholesale, and retail services). For example, in the case of a shirt purchased from a retail outlet, the purchaser's price is the price paid by the consumer in the retail outlet whereas the producer's price is the price of the shirt when it leaves the factory.

The first step in breaking down final consumption expenditure into its value added components is therefore to convert final consumption expenditure measured in purchaser's prices into those measured in producer's prices. This amounts to removing distribution costs from final consumption expenditure on goods and moving them into expenditure on services. The Online Appendix B.1 explains the details of this calculation. Once this is done, the second step is to use the input–output tables to determine the sectoral inputs in terms of value added that are required to deliver the final consumption expenditure. This involves an object called the total requirement matrix which is derived from the input–output tables. The Online Appendix B.2 explains the details of this procedure.

Two points are worth stressing. First, since we are interested in the time series properties of consumption value added, and the structure of input–output relationships changes over time, an important feature of our calculation is that we use all annual input–output tables together with all benchmark tables that are available for the period 1947–2010. Second, when we break final consumption expenditure into its value added components we follow the BEA and treat imported goods as if they were produced domestically with the same technology that the United States uses to produce them. Given this assumption, we do not have to take a stand on whether intermediate goods are produced domestically or imported.[16]

Having broken final consumption expenditure into its value added components, we obtain data on consumption value added expenditure shares and chain–weighted prices and quantities, which are displayed in Figures 9–11. Note that these figures display the same qualitative pattern for consumption value added shares that we saw in the analogous figure for final consumption expenditure shares. Hence, both representations are consistent with the stylized facts about structural transformation. However, although the shares display similar qualitative behavior, there are some important differences in the behavior of relative prices and quantities. First, Figure 10 shows that while the price of services still increased the most, the price of manufacturing now increased by more than that of agriculture. Second, the relative quantities behave very differently from before. Whereas Figure 3 indicated substantial changes in relative quantities, Figure 11 suggests that the relative quantities of manufacturing and services now hardly change over the entire period, while the relative quantity of agriculture remains fairly constant after about 1970.

We report formal estimation results in the next section, but we can already note that these figures are revealing about the economic mechanisms at work. Given that relative prices changed substantially, the near constancy of relative quantities, particularly of manufacturing relative to services, suggests a very low degree of substitutability between the different components of consumption value added. Moreover, the near constancy of the relative agricultural quantity after 1970 suggests that nonhomotheticities will not play

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[16]The Online Appendix B.2 explains this point in more detail.

Table 3—Results with Consumption Value Added

	(1)	(2)	(3)
σ	0.002	0	0
	(0.001)	–	–
$\bar{c}_a$	−138.68**	−138.88**	
	(4.57)	(16.04)	
$\bar{c}_s$	4261.82**	4268.06**	
	(223.78)	(439.93)	
ω_a	0.002**	0.002	0.01**
	(0.0002)	(0.001)	(0.001)
ω_m	0.15**	0.15**	0.18**
	(0.002)	(0.004)	(0.002)
ω_s	0.85**	0.85**	0.81**
	(0.002)	(0.004)	(0.003)
$\chi^2(\bar{c}_a = 0, \bar{c}_s = 0)$	1424.50**	216.30**	
AIC	−873.27	−875.36	−739.35
$RMSE_a$	0.005	0.005	0.010
$RMSE_m$	0.012	0.012	0.019
$RMSE_s$	0.011	0.011	0.024

Robust standard errors in parentheses * $p < 0.05$, ** $p < 0.01$

χ^2 is the Wald Test Statistics for the hypothesis that $\bar{c}_a$ and $\bar{c}_s = 0$ are jointly zero.
AIC is the Akaike information criterion, $RMSE_i$ is the root mean squared error for equation i.

as important a role as before.

B. Results with Consumption Value Added

We follow the same procedure as was described previously in the context of estimating parameters using data on final consumption expenditure. Results are contained in Table 3. Column (1) reports the parameter estimates when we impose no restrictions. Strikingly, the point estimate of σ is equal to 0.002 and is not statistically significantly different from zero, which in the absence of nonhomotheticities implies the Leontief specification.[17] The nonhomothetic terms have the same signs as before, and the chi-squared tests again reject the hypothesis that both are zero. Given that the unrestricted estimated value of σ is so close to zero and not statistically different from zero, Column (2) shows the estimates when we impose $\sigma = 0$. Note that while the root mean squared errors remain unchanged, the AIC actually decreases as we move from Column (1) to Column (2), suggesting that the restricted version of Column (2) is preferable to

[17] The corresponding Leontief utility function is given by $\min_{j=\{a,m,s\}}\{c_{jt}/\omega_j\}$.

TABLE 4—NONHOMOTHETICITY TERMS RELATIVE TO CONSUMPTION FROM THE DATA

	1947	2010
$-p_a\bar{c}_a/C$	0.08	0.004
$p_s\bar{c}_s/C$	0.34	0.12
$-\bar{c}_a/c_a$	0.86	0.32
$\bar{c}_s/c_s$	0.53	0.14

the unrestricted version of Column (1). Figure 12 confirms that based on the estimates in Column (2), the fit of the model to the expenditure share data is again very good.[18]

C.   Income versus Price Effects with Consumption Value Added

It is again of interest to ask how important income and relative price changes are in accounting for the observed changes in the expenditure shares of consumption value added. As a starting point it is revealing to look again at the size of the estimated $\bar{c}_i$'s relative to total consumption expenditure from the data. The first two rows of Table 4 show that these ratios are now considerably smaller than in the case of final consumption expenditure. Although this suggests that income effects will be less important than in the final expenditure case, the fact that in 1947 the agricultural consumption value added from the data was fairly close to $\bar{c}_a$, it is likely that these terms still plays a significant role.

A first method for assessing the importance of income and substitution effects is to evaluate the ability of a homothetic specification to fit the data. To examine this, Column (3) in Table 3 presents estimates under the restriction $\bar{c}_a = \bar{c}_s = 0$. Note that the Akaike information criterion increases significantly, as do each of the root mean square errors, suggesting a deterioration in terms of goodness of fit, though the change is not as large as we found for the same exercise in the final expenditure specification. Consistent with this, when we plot the expenditure shares predicted by the estimated homothetic specification from Column (3) in Figure 13, and compare them to the nonhomothetic specification of Figure 12, the visual fit remains reasonably good.

A second method for assessing the importance of income and substitution effects is to repeat the counterfactual exercises that we previously carried out for the final expenditure case. Specifically, Figure 14 shows the implied path for expenditure shares under the counterfactual in which relative prices stay fixed at their 1947 values and total expenditure rises as in the data. While this counterfactual does account for some of the secular changes in expenditure shares, it is evident that the fit is much worse than in Figure 12. This shows that changes in relative prices now play a much more important role in accounting for the movements in expenditure shares. Figure 15 shows the alternative counterfactual, in which we keep total expenditure fixed at its 1947 level but allow relative prices to changes as in the data. While this figure does confirm that changes in

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[18]The reason why the AIC decreases is that it penalizes using additional parameters.

Fit of Expenditure Shares with Consumption Value Added
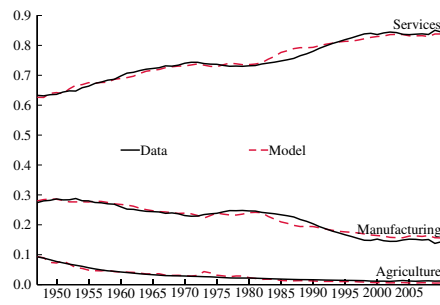
Figure 12. Fit of Column (2)

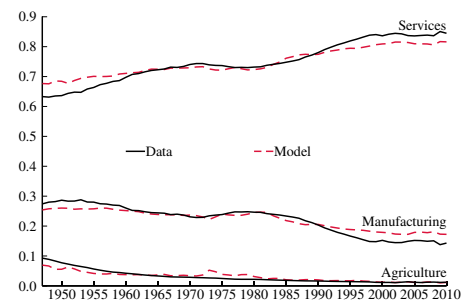Figure 13. Fit of Homothetic Specification in Column (3)

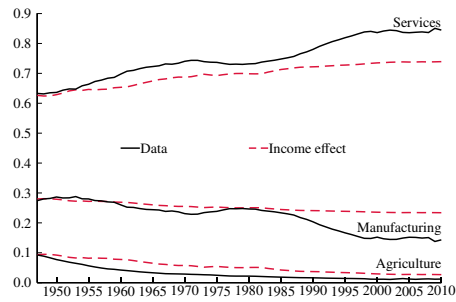Figure 14. Fit of Column (2) with Prices Fixed at 1947 Value

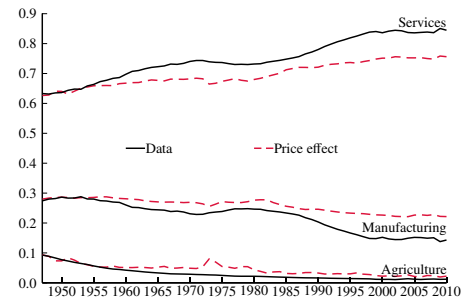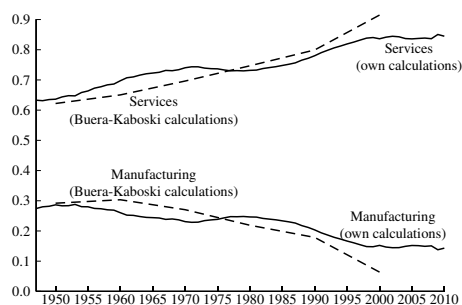Figure 15. Fit of Column (2) with Income Fixed at 1947 Value

FIGURE 16. SHARES IN CONSUMPTION VALUE ADDED WITH DIFFERENT WAYS OF TREATING INVESTMENT

relative prices do play an important role now, it also makes it clear that price effects alone cannot account for the changes in expenditure shares.

We conclude that the econometrically preferred specification implies an economically significant role for both income and price effects in accounting for changes in expenditure shares. Notably, the preferred value of σ is not statistically different from zero. Nonetheless, from a practical perspective, the consumption value added data provide some measure of support for the homothetic preference specification used by Ngai and Pissarides, though in the somewhat extreme form of a Leontief specification, i.e. $\sigma = 0$.

Since introspection would suggest substantial willingness to substitute across many commodities, some readers might question the empirical plausibility of preferences that do not permit any substitution across the consumption value added categories agriculture, manufacturing, and services. It is therefore important to understand exactly what the result $\sigma = 0$ means. Although having $\sigma = 0$ implies that there is no substitutability across the three categories, it is completely consistent with there being substantial substitution *within* each of these categories. In particular, since the categories are quite broad, having $\sigma = 0$ does not in any sense imply that there is no substitutability between all the different goods and services that individuals consume.

A simple example may be useful. Most readers will agree that there is some substitutability between the two activities of going to the movies and going to sporting events. When we represent these activities in consumption value added terms, we see that both of them involve some consumption of goods (e.g., the use of buildings) and some consumption of services (e.g., actors and athletes producing entertainment services). It seems reasonable to think that the key dimensions of substitution are within these two value added categories, i.e., that the key substitution is between the uses of buildings or the uses of athletes' and entertainers' time, rather than between goods and services per se. While this is not to suggest that one cannot think of specific examples with some substitution between specific goods and specific services, the key point we want to make is that there is likely to be considerably more substitutability within each of the value added categories.

D. Related Literature

In independent research, Buera and Kaboski (2009) asked whether there are parameters for which a canonical model of structural transformation can match the time series for sector shares in the US. While this question is closely related to our work, there are several important differences between the two papers. First, Buera and Kaboski considered a longer time period than we do, 1870 to 2000. Although there is clearly some benefit of extending the analysis further back in time when assessing the ability of the model to account for secular changes, the cost of doing this is that comparable data do not exist for the pre 1947 period, thereby forcing several compromises.[19] Second, Buera and Kaboski only looked at value added data, whereas one of our main contributions is to contrast the implications of matching value added data versus final expenditure data.

Perhaps the most important difference between the two papers is that although Buera and Kaboski also found that a low σ provides the best fit to the value–added data, they reach the conclusion that the canonical model of structural transformation cannot do a good job of accounting for the key secular patterns of sectoral value added shares in the later part of the sample period. Specifically, they argued that the data for the post 1960 period show both an increase in the relative price of services and an increase in the relative share of services, and that Stone–Geary preferences cannot generate these outcomes this late in the time series when the bite coming from the non–homotheticity term in services has all but faded; see the pages 473–4 of their paper for more details.

Why do the two studies reach such different conclusions about the ability of the model to fit the data? The key to answering this question lies in the different ways of treating investment. Whereas we extract the consumption component from sectoral value added by decomposing investment value added into its manufacturing and service components, Buera and Kaboski followed the standard way of proceeding in the literature and assumed that all investment value added is produced in manufacturing. This means that their consumption value added produced in services equals the total services value added and their consumption value added produced in manufacturing equals the total manufacturing value added minus the total investment value added. As we noted earlier, this approach runs into a basic problem in 1999, since at this point investment value added in the data actually exceeds total manufacturing value added. It turns out that Buera and Kaboski define the manufacturing sector more broadly than is typically done, therefore avoiding this problem during their sample period.[20]

But a second problem remains when one assumes that all of investment represents value added from the manufacturing sector. This problem arises because the sectoral composition of investment in the post 1947 period has changed dramatically: while in 1947 the shares of manufacturing and services valued added in investment value added

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[19]For example, Buera and Kaboski were forced to use data for sector expenditure shares and prices that are not necessarily mutually consistent. Specifically, they use the implicit deflator of services in NIPA and the producer price index of finished goods from the BLS. The former is based on gross sales while the latter is based on final expenditure. In contrast, we use price indices that are based on value added.

[20]Based on their definition of manufacturing, the share of their manufacturing sector in total value added in 1947 is about ten percentage points larger and the share of the service sector in total value added is about ten percentage points smaller than the shares resulting from the standard definition that we use.

were roughly 2/3 and 1/3 respectively, as of 2010 they are roughly 1/2 and 1/2. Neglecting this change in the composition of investment while assuming that all of investment represents value added from the manufacturing sector leads to a spurious increase in the growth rate of the share of services in total consumption value added and a spurious decrease in the growth rate of the share of manufacturing in total consumption value added towards the end of the sample. Figure 16 shows this by comparing our consumption value added shares with the consumption value added shares that one gets by subtracting total investment value added as reported by the BEA data from the series of manufacturing value added used by Buera and Kaboski.

IV.   Discussion

A.   *Comparing the Results*

Although each of the estimation exercises yield utility specifications that provide very good fits to their respective data sets, the specifications have very different implications for the relative importance of changes in relative prices and income in accounting for changes in expenditure shares. In the case of final consumption expenditure, income effects are the dominant force behind changes in the expenditure shares, whereas in the case of consumption value added income effects are less important and relative price effects are found to play a key role.

As we have stressed previously, given the technology for producing final expenditure categories from value added categories, there is an implicit mapping from preferences defined over final expenditure categories to preferences defined over value added categories. In this section we explore the properties of this mapping in order to reconcile the two very different estimated utility functions. Before delving into the details, it might be instructive to build some intuition. The intuition is sharpest if we focus on two consumption items: food from supermarkets and meals from restaurants.

<div align="center">INTUITION</div>

The intuition for greater substitutability in the final consumption expenditure specification is closely related to the fact that this specification may place items with similar underlying characteristics into different categories. To stay with our example, this method counts food from supermarkets in agriculture, while meals from restaurants are counted in services. One would expect there to be substitutability between the two items because they both use the intermediate input food. In contrast, in the consumption value added specification, all agricultural inputs into food production are counted in the agriculture sector, removing this source of substitutability.

The differing importance of nonhomotheticities is also intuitive. In the final consumption expenditure specification, for example, it is natural to think that food from supermarkets is a necessity, thereby leading to a negative value for $\bar{c}_a$. Similarly, it is natural to think that many services such as restaurant meals are more of a luxury, thereby leading to a positive value for $\bar{c}_s$. However, this reasoning does not apply to the consumption value added specification, since the category labeled agriculture now contains the agricultural

inputs that went both into the production of "necessary" food and "luxury" restaurant meals. It follows that the nonhomotheticities should be less apparent in the consumption value added specification.

We now turn to the mapping from preferences defined over final expenditure categories to preferences defined over value added categories. We start from some given preferences over final consumption goods and assume that the household self–produces final consumption goods by combining the different consumption value added categories. We derive the form of preferences over consumption value added that is implied by the preferences over final consumption goods and the production technology that specifies how the household obtains final consumption goods from consumption value added. Because our empirical strategy was to uncover preference parameters by estimating the expenditure systems, our approach will emphasize how the expenditure system for consumption value added is derived from the expenditure system for final consumption expenditure.

<div style="text-align:center">Formal analysis</div>

To derive the mapping from preferences defined over final expenditure categories to preferences defined over value added categories, we need to specify how final consumption goods are produced from the different value added categories. We assume that the corresponding production functions have the CES functional form:

$$
(5) \qquad c_{it}^{FE} = \left[\sum_{j \in \{a,m,s\}} (A_{it}\phi_{ji})^{\frac{1}{\eta_i}} \left(c_{jit}^{VA}\right)^{\frac{\eta_i-1}{\eta_i}} \right]^{\frac{\eta_i}{\eta_i-1}},
$$

where c_{jit}^{VA} is the value added from sector j that is used as an intermediate input in the production of the final consumption good c_{it}^{FE}, A_{it} determines the TFP of producing final consumption of category i, ϕ_{ji} are relative weights with $\sum_j \phi_{ji} = 1$, and $\eta_i > 0$ is the elasticity of substitution.

The household's demand functions for c_{jit}^{VA} are obtained by minimizing the costs of producing a given quantity c_{it}^{FE} subject to (5) taking the p_{jt}^{VA} as given. The resulting demand functions take the familiar form:

$$
(6) \qquad p_{jt}^{VA} c_{jit}^{VA} = \frac{\phi_{ji} \left(p_{jt}^{VA}\right)^{1-\eta_i}}{\sum_{n \in \{a,m,s\}} \phi_{ni} \left(p_{nt}^{VA}\right)^{1-\eta_i}} p_{it}^{FE} c_{it}^{FE},
$$

where we have used the identity $\sum_{j \in \{a,m,s\}} p_{jt}^{VA} c_{jit}^{VA} = p_{it}^{FE} c_{it}^{FE}$.

The next step in the derivation of the demand system for consumption value added is to aggregate the demands for c_{jit}^{VA} to the demand for c_{jt}^{VA}. Summing equation (6) over i,

we obtain:

$$(7) \qquad p_{jt}^{VA} c_{jt}^{VA} = \sum_{i \in \{a,m,s\}} \frac{\phi_{ji} \left(p_{jt}^{VA} \right)^{1-\eta_i}}{\sum_{n \in \{a,m,s\}} \phi_{ni} \left(p_{nt}^{VA} \right)^{1-\eta_i}} p_{it}^{FE} c_{it}^{FE} .$$

One can express (7) as a standard demand system for consumption value added that depends only on the p_{jt}^{VA} and on $P_t C_t = \sum_{i \in \{a,m,s\}} p_{it}^{FE} c_{it}^{FE}$. This involves two steps: substitute in the demand functions for $p_{it}^{FE} c_{it}^{FE}$, which depend on p_{it}^{FE} and $P_t C_t$ and then use that final–expenditure prices are given by the following price index:

$$(8) \qquad p_{it}^{FE} = \left[\sum_{n \in \{a,m,s\}} A_{it} \phi_{ni} \left(p_{nt}^{VA} \right)^{1-\eta_i} \right]^{\frac{1}{1-\eta_i}} .$$

At a general level there is not much that we can say about this resulting demand system, and it may not even be consistent with the functional form for preferences over value added consumptions that we imposed in our estimation. But given our estimation results, a useful starting point is to ask whether there are any conditions under which the demand system (7) can be consistent with a Leontief utility function over value added. While the data do not imply that Leontief is the preferred specification for the value added case, we did find that this specification still provides a reasonable fit to the data, and focusing on it serves to highlight how the finale expenditure and value added expenditure systems can have very different properties. To proceed, suppose that the following condition holds:

$$(9) \qquad \eta_i = 0 \quad \text{and} \quad \phi_{ji} = \phi_j \quad \forall i \in \{a, m, s\}.$$

Simple manipulation of (7) leads to:

$$(10) \qquad p_{jt}^{VA} c_{jt}^{VA} = \frac{\phi_j p_{jt}^{VA}}{\sum_{n \in \{a,m,s\}} \phi_n p_{nt}^{VA}} \sum_{i \in \{a,m,s\}} p_{it}^{FE} c_{it}^{FE} = \frac{\phi_j p_{jt}^{VA}}{\sum_{n \in \{a,m,s\}} \phi_n p_{nt}^{VA}} P_t C_t.$$

This is readily seen to be the demand system that is implied by a Leontief utility function.

The condition $\eta_i = 0$ means that the production functions (5) have the Leontief form and $\phi_{ji} = \phi_j$ means that the intermediate input from a given sector has the same weight in the production of all three final consumption goods. In this case, the aggregate intermediate inputs are not substitutable and each aggregate intermediate input has the same weight in the production of total final consumption as it has in the production of each of the three final consumption categories. Intuitively, this implies that the demand for intermediate inputs from a given sector is independent of the composition of final consumption. As a result both substitution and income effects present in the final consumption expenditure system vanish in the consumption value added expenditure system, because the reallocation of final consumption expenditure in response to income changes does not necessitate a reallocation of consumption value added.

	Agriculture	Manufacturing	Services
η_i	0.19**	0.001	0.001
	(0.03)	(0.001)	(0.0003)
ϕ_{ai}	0.05**	0.02**	0.005**
	(0.002)	(0.001)	(0.0002)
ϕ_{mi}	0.33**	0.36**	0.09**
	(0.003)	(0.002)	(0.001)
ϕ_{si}	0.62**	0.62**	0.90**
	(0.005)	(0.002)	(0.001)
AIC	−657.99	−790.10	−896.63

Robust standard errors in parentheses * $p < 0.05$, ** $p < 0.01$
AIC is the Akaike information criterion, $RMSE_i$ is the root mean squared error for equation i.

Having isolated theoretical conditions under which the value added demand system is consistent with Leontief preferences, we now turn to assessing the empirical relevance of these conditions. In this context, it is important to recall that while a Leontief specification gives a reasonable fit, the statistically preferred specification features significant non–homotheticity terms, and so is not a Leontief specification. In other words, there is no presumption that condition (9) will hold in the data.

Given observations of p_{jt}^{VA}, $p_{jt}^{VA} c_{jt}^{VA}$, and $p_{it}^{FE} c_{it}^{FE}$, we estimate the parameters η_i and ϕ_{ni} in equation (7) similar to the way that we estimated demand systems in the previous sections. The results are in Table 5. The point estimates for the η's come out surprisingly close to zero, and for η_m and η_s they are not statistically different from zero. We conclude that the first condition in (9) is approximately born out the data. The evidence regarding the second condition in (9) is less favorable. While some values in a given row are very similar, there are differences that are quite large and statistically significant. Nonetheless, it is still possible that the demand system generated by a Leontief utility function may provide a reasonable fit to the data on consumption value added. To see why this is the case, note that (10) can be written as:

$$(11) \qquad p_{jt}^{VA} c_{jt}^{VA} = \Phi_{jt} \frac{\phi_j p_{jt}^{VA}}{\sum_{n \in \{a,m,s\}} \phi_n p_{nt}^{VA}} P_t C_t,$$

where

$$(12) \qquad \Phi_{jt} = \sum_{i \in \{a,m,s\}} \left(\frac{\phi_{ji} p_{jt}^{VA}}{\phi_j p_{jt}^{VA}} \frac{\sum_{n \in \{a,m,s\}} \phi_n p_{nt}^{VA}}{\sum_{n \in \{a,m,s\}} \phi_{ni} p_{nt}^{VA}} \right) \frac{p_{it}^{FE} c_{it}^{FE}}{P_t C_t}.$$

Demand system (11) is consistent with a Leontief utility function as long as $\Phi_{jt} = 1$.

Condition (9) is sufficient for this to hold. Even if (9) does not hold, the departures from $\Phi_{jt} = 1$ may be small quantitatively so that a utility function close to a Leontief utility function can still provide a good fit.

In summary, the discussion in this subsection illustrates in a unified setting how a given economy can be consistent with two very different expenditure systems expressed in final expenditure and value added form. To do so, we focussed on the benchmark functional forms Stone–Geary and Leontief. Even though these are not the exact specifications from our estimation exercises, each does provide a reasonable fit to the data. The advantage of using them in this context instead of the econometrically preferred specification is that they imply simple closed–form expressions for the expenditure systems, which are helpful for purposes of exposition.

B. Additional Measurement Issues

In this subsection we note several measurement concerns and carry out some robustness exercises motivated by these concerns.

GOVERNMENT

Our previous results implicitly assumed that households were purchasing government services at the price p_s. An alternative assumption is that households take the provision of government services as given and then make a decision about how many additional services to purchase privately in the market. In this subsection we present results for this alternative assumption.

We begin with the final consumption expenditure specification. Maintaining the assumption that government services are a perfect substitute for services that are purchased in the market, the alternative approach is equivalent to treating the provision of government services as a time varying component of $\bar{c}_s$. Estimation results for this case are provided in Table 6. For ease of comparison, Columns (1) and (2) report the earlier results for our benchmark case when σ is left unrestricted and when σ is restricted to equal one, respectively. Columns (3) and (4) do the equivalent exercise for the case in which we treat government spending as a time varying component of $\bar{c}_s$, and Figures 17 and 18 display the fit of the two estimated specifications. The main finding is that our earlier conclusions continue to hold. Specifically, while Stone–Geary is not the preferred econometric specification, a Stone–Geary specification does provide a good fit to the data.[21]

Next we consider the same exercise for the case of value added consumption. Note that because value added from government consumption can contain components from all three sectors, in contrast to the final consumption expenditure case, this case involves time varying non–homotheticity terms for all three sectors. Results are shown in Table 7,

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[21]Based on both the AIC values and the root mean square errors, this treatment of government expenditures seems to provide a somewhat worse fit to the data than our benchmark specification, but it is important to note that under this alternative specification these diagnostics reflect the ability of the model to match the expenditure share for private consumption of services, whereas in the benchmark model the diagnostics reflect the ability of the model to match the total expenditure share for services.

TABLE 6—RESULTS FOR FINAL CONSUMPTION EXPENDITURE AND DIFFERENT SPECIFICATIONS OF GOVERNMENT EXPENDITURES

	$(c_{s\backslash g} + c_g) + \bar{c}_s$		$c_{s\backslash g} + (c_g + \bar{c}_s)$	
	(1)	(2)	(3)	(4)
σ	0.85**	1.00	0.80**	1.00
	(0.06)	–	(0.05)	–
$\bar{c}_a$	−1350.38**	−1315.99**	−1360.93**	−1314.89**
	(31.18)	(26.48)	(29.83)	(26.40)
$\bar{c}_s$	11237.40**	19748.22**	7254.04**	14685.83**
	(2840.77)	(1275.69)	(1806.82)	(1045.21)
ω_a	0.02**	0.02**	0.02**	0.02**
	(0.001)	(0.001)	(0.001)	(0.001)
ω_m	0.17**	0.15**	0.19**	0.16**
	(0.01)	(0.004)	(0.01)	(0.005)
ω_s	0.81**	0.84**	0.79**	0.82**
	(0.01)	(0.005)	(0.01)	(0.01)
Average c_g			5283.67	5283.67
AIC	−932.55	−931.35	−856.26	−853.56
$RMSE_a$	0.004	0.004	0.030	0.030
$RMSE_m$	0.009	0.009	0.066	0.066
$RMSE_s$	0.010	0.011	0.095	0.095

Robust standard errors in parentheses * $p < 0.05$, ** $p < 0.01$
AIC is the Akaike information criterion, $RMSE_i$ is the root mean squared error for equation i.

Final Consumption Expenditure and different Specifications of Government Expenditures
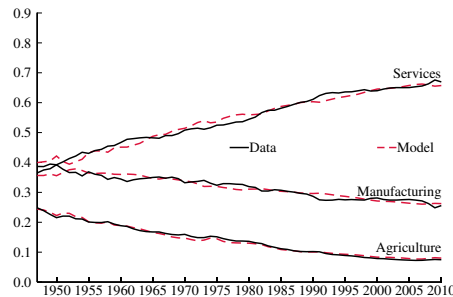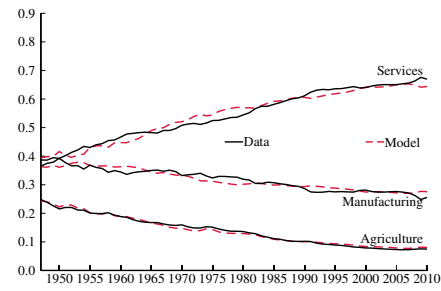
FIGURE 17. FIT OF COLUMN (3)

FIGURE 18. FIT OF COLUMN (4)

TABLE 7—RESULTS FOR CONSUMPTION VALUE ADDED AND DIFFERENT SPECIFICATIONS OF GOVERNMENT EXPENDITURES

	$(c_{s\backslash g} + c_g) + \bar{c}_s$ (1)	$c_{s\backslash g} + (c_g + \bar{c}_s)$ (2)
σ	0.002	0.001
	(0.001)	(0.001)
$\bar{c}_a$	-138.68^{**}	-140.53^{**}
	(4.57)	(4.33)
$\bar{c}_s$	4261.82^{**}	5712.68^{**}
	(223.79)	(225.99)
ω_a	0.002^{**}	0.001^{**}
	(0.0002)	(0.0002)
ω_m	0.15^{**}	0.14^{**}
	(0.002)	(0.002)
ω_s	0.85^{**}	0.86^{**}
	(0.002)	(0.003)
Average c_{ag}		21.02
Average c_{mg}		516.95
Average c_{sg}		3906.44
AIC	-873.27	-812.14
$RMSE_a$	0.005	0.008
$RMSE_m$	0.012	0.023
$RMSE_s$	0.011	0.026

Robust standard errors in parentheses * $p < 0.05$, ** $p < 0.01$
AIC is the Akaike information criterion, $RMSE_i$ is the root mean squared error for equation i.

where for ease of comparison we have included the results of our earlier benchmark estimation in column (1) and column (2) presents the results when government expenditure are taken as given. Figure 19 shows the ability of the specification in column (2) to fit the data. Comparing the results in columns (1) and (2) and looking at Figure 19, we see that our earlier results are virtually unaffected. Consistent with the results for the final expenditure case, we do see a small increase in the value of the AIC and higher root mean square standard errors.

We conclude that our main findings are robust to this alternative treatment of government services.

UNMEASURED QUALITY IMPROVEMENTS

An important issue when examining time series changes in prices and quantities is the extent to which the data take proper account of quality improvements. Failure to do so will bias the decomposition of expenditure shares into price and quantity components.

FIGURE 19. CONSUMPTION VALUE ADDED AND DIFFERENT SPECIFICATIONS OF GOVERNMENT EXPENDITURES – FIT OF COLUMN (2)
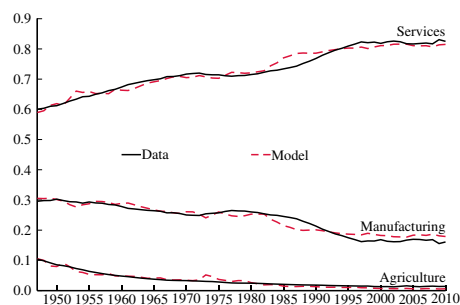
In particular, if the quality of a consumption category has improved but this is not measured properly, then the reported price will be larger than the true price and the reported quantity will smaller than the true quantity (while of course the reported expenditure are the same in both cases).

A key limitation of the official data used in our analysis is that effectively no corrections are made to allow for quality improvements in services. Absent a systematic treatment of quality improvements that extends over a long time period it is difficult to provide a definitive assessment of how this issue might impact our findings. However, we can provide some illustrative calculations based on the findings of the report by Boskin et al. (1996) on the extent of quality change bias in the CPI during the period 1965–1996 (where quality change bias as they measure it results both from unmeasured quality improvements and from unmeasured introduction of new goods).

Calculating annual averages for our three sectors, their numbers imply quality change biases for the final expenditure on agriculture, manufacturing, and services equal to 0.3%, 0.5%, and 0.6%. We use these annual estimates for our final expenditure approach, assuming that they are also applicable outside of the time period 1965–1996. The results of redoing the estimation with these quality adjustments are in Table 8. We can see that the estimated value of σ is slightly closer to one and the absolute values of both non–homotheticity terms are reduced somewhat but still large. Intuitively, the quality adjustment implies that the relative price of services increases less than in our benchmark specification, so that for a given value of σ there is less need for $\bar{c}_s$ to offset the substitution away from services due to the higher relative price.

We conclude that implementing the quality adjustments consistent with the estimates in Boskin et al. (1996) has little impact on our findings for final consumption expenditure. It would be of interest to assess the importance of quality change bias also for consumption value added. Unfortunately, Boskin etal offer estimates only for final expenditure categories in the CPI.[22]

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[22]One might think that we could use the input–output tables to back out what the implied unmeasured quality improvements for value added must have been. This idea is not promising, however, because the input–output relationships come in terms of current prices, and so it is unclear how to decomposed them into quantities and prices, which are required to

TABLE 8—RESULTS FOR FINAL CONSUMPTION EXPENDITURES WITH QUALITY ADJUSTMENT

	Original	Quality adjusted
σ	0.85**	0.90**
	(0.06)	(0.06)
$\bar{c}_a$	−1350.38**	−1046.19**
	(31.18)	(31.05)
$\bar{c}_s$	11237.40**	7478.75**
	(2840.77)	(1403.05)
ω_a	0.02**	0.03**
	(0.001)	(0.001)
ω_m	0.17**	0.18**
	(0.01)	(0.01)
ω_s	0.81**	0.78**
	(0.01)	(0.01)
AIC	−932.55	−924.70
$RMSE_a$	0.004	0.005
$RMSE_m$	0.009	0.008
$RMSE_s$	0.010	0.010

Robust standard errors in parentheses * $p < 0.05$, ** $p < 0.01$

AIC is the Akaike information criterion, $RMSE_i$ is the root mean squared error for equation i.

HOME PRODUCTION

Our model has abstracted from the explicit consideration of home production. Given that most home production takes the form of services, Kongsamut, Rebelo and Xie (2001) suggested that the parameter $\bar{c}_s$ could be interpreted as the level of home produced services, under the assumption that home produced services are a perfect substitute for market produced services. More generally, one might simply posit that the parameter $\bar{c}_s$ captures both the presence of home production and a possible nonhomotheticity in the preferences for services. This interpretation raises two issues for our analysis, each of which we discuss in turn.

First, to what extent does home production enter our two different specifications in a symmetric fashion? Consider one prominent example of home production: the provision of child care services. In the final consumption expenditure specification, all of the child care services purchased in the market would be counted in services. In the value added approach we would have to decompose the production of market provided child care services into its various components. To the extent that the two dominant inputs will be labor and real estate space, the value added approach will also mostly assign the production of market provided child care to the services category. More generally, as long as time is the key input into those market activities which are good substitutes for

make the quality adjustments.

home production, it is reasonable to think that home production will enter symmetrically into the two different specifications. We believe that this applies to activities such as child care, elderly care, cleaning, and home maintenance.

But while we think this symmetry is valid for a large share of home production activities, it does not apply for all of them. For example, in the case of home cooked meals versus meals purchased in restaurants, the symmetry is broken because the value added approach will assign the food used in the restaurant to other sectors, with the breakdown depending on the extent to which the food has been processed. However, it should be noted that about 45% of the price of food purchased at a supermarket represents value added from distribution services and retail, which are in the service sector.[23] In view of this, we believe it is reasonable as a first pass to assume that home produced output enters the two specifications in a symmetric fashion. Note that the value of $\bar{c}_s$ need not be the same in the two specifications since home production is simply one component of $\bar{c}_s$.

The second issue concerns the constancy of home production over time. Even if only part of $\bar{c}_s$ represents home production, any variation in home production over time would induce variation in the value of $\bar{c}_s$ over time, whereas our empirical work has treated this parameter as constant. Given that Aguiar and Hurst (2007) and Ramey and Francis (2009) both documented a sharp drop in time devoted to home production associated with the dramatic increase in the participation rate of married women, it is possible that this assumption is problematic. Before pursuing this possibility further, we note two important qualifications. First, what matters in our specification is the output of home production and not simply the time input. To the extent that technological progress has lessened the amount of time required to produce output at home, the reduction in time spent in home production need not imply a decrease in the quantity of home produced output. Even if home produced output is constant it will still account for a declining share of overall consumption. Second, as emphasized by Ramey and Francis (2009), although individuals are spending less time in home production during their prime age years, older individuals engage in more home production time than prime aged individuals and the increase in life expectancy creates an opposing effect in terms of aggregate time devoted to home production.

In order to allow for the possibility that there has been a secular trend in the amount of home produced output over the time period being considered, we have redone our estimation exercise for the consumption value added specification allowing for a constant growth rate in the value of $\bar{c}_s$, i.e., we assume that $\bar{c}_s$ is time varying with $\bar{c}_{st} = \exp(\gamma t)\bar{c}_s$. We carry out the same procedure as previously, except that we now also estimate the parameter γ. When we do this we obtain estimates of γ that are not significantly different from zero, and the estimated values of the other parameters are virtually unchanged, suggesting that imposing a constant $\bar{c}_s$ is not restrictive in our context.

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[23] The average distribution margin over the period 1947–2010 we calculated is 45%.

TABLE 9—DECOMPOSITION OF INCREASE IN EXPENDITURE SHARE OF SERVICES IN VALUE ADDED (ACCUMULATED 1947–2010)

Category	%
Finance, Insurance, Real Estate, Rental, and Leasing	46.9
Professional and Business Services	41.1
Health Care and Social Assistance	27.9
Information	6.9
Utilities	1.8
Educational Services	3.7
Government	5.0
Arts, Entertainment, Recreation, Accommodation, Food Services, and Other	−0.1
Trade and Transport	−33.2
	100.0

OTHER ISSUES

In this subsection we note two other issues. The first concerns the fact that consumption of durable goods typically does not equal expenditure on durable goods. For housing, which is by far the most prominent example of durables, the BEA takes account of this and imputes the rents for owner–occupied houses. For all other durables, the BEA reports expenditure (or value added) only, which forces us to associate the expenditures on these durables with current consumption. This implies, for example, that current period utility from automobiles is derived solely from current period sales of automobiles, and so we do not attribute any current period utility flow to the stock of automobiles purchased in previous periods. Because we are focused on longer term trends in aggregate data, this is not likely to be as serious as it would be in looking at individual data, or business cycle fluctuations; but it is an issue worth noting.

The second issue concerns the possibility that reallocation of resources across sectors reflects a relabeling of activity due to outsourcing, as opposed to fundamental shifts of economic activity across sectors. For example, if a car manufacturer changes from having in–house security guards at its establishments to purchasing security services from an outside firm, the data will record this as a movement of value added across sectors.[24] This phenomenon will bias the measurement of changes in the expenditure shares of consumption value added. However, this bias is not likely to be a major driving force of structural transformation at the level of aggregation that we consider. The main reason is that industry classifications are done at the establishment level, implying that all in–house services provided at a central administrative office (headquarters) or a separate service–providing unit are classified as service industries.

There are two additional ways of establishing that outsourcing is not the major force behind structural transformation. First, Table 9 decomposes the accumulated increase in the expenditure share of service consumption value added into the contributions of ten

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[24]Fuchs (1968) suggested that this is one of the driving forces behind the process of structural transformation.

subcategories of services, where outsourced services are part of the subcategory Professional and Business Services. Although this category is the second biggest contributor to the overall increase in the expenditure share of services, more than half of the increase is accounted for by other categories. Moreover, it is reasonable to think that a substantial share of the increase in business and professional services reflects purchases directly made by consumers, in which case they would not be subject to outsourcing. A second way of establishing that outsourcing is not the major force behind structural transformation is to look at what happened to final consumption expenditure, instead of consumption value added, because final consumption expenditure are not affected by outsourcing. To stay with the example of the car manufacturer, all that matters with final consumption expenditure is how much is spent on purchases of cars. Holding the price and quantity of security services fixed, it does not matter if the security services that are implicitly reflected in the price of cars were supplied in–house or outsourced. The fact that the changes in the shares are very evident in the final consumption expenditure data confirms that the process of structural transformation is not mainly a process of outsourcing.

V.   Conclusion

What utility function should one use in applied work on structural transformation and related issues? This paper provides an answer to this simple question by examining the behavior of household expenditure shares for the US economy over the period 1947 to 2010. In answering this question, our analysis offers three contributions.

The first contribution of this paper is to clarify that given common practice in specifying multi–sector general equilibrium models, the previous question requires two answers, one for each of two different methods of defining commodities in such models.

The second contribution of this paper is to supply the two answers. A key step in achieving this is to develop and execute a procedure for producing time series data on consumption value added. This requires extracting the component of total value added by sector that corresponds to consumption value added. A priori there is little guidance as to how different (or similar) the two answers might be. It is noteworthy that we find the answers to be dramatically different in terms of their basic properties. Interestingly, each of the answers can be approximated by a simple functional form. If one adopts the final consumption expenditure specification, then a Stone–Geary utility function provides a good fit to the US time series data. If instead one adopts the consumption value added specification, then a homothetic Leontief utility provides a reasonable fit to the data, although the preferred econometric specification does include non–homotheticity terms.

The third contribution of this paper is to shed light on how the two different specifications of preferences are connected via technology and the nature of input–output relationships. In particular, we derive a sufficient condition under which a Stone–Geary utility function over final consumption expenditure is consistent with a Leontief utility function defined over consumption value added.

While the utility functions that we estimate are specifically relevant for models of structural transformation, some of the basic messages of the analysis are much more

general. In particular, researchers must be careful to apply consistent definitions of commodities on both the household and production sides when connecting models with data in any multi–sector general equilibrium analysis. Changing the definition of what is meant, for example, by the label "services" has implications not only on the household side for what form of utility function is appropriate, but also on the production side for such things as the measurement of productivity growth. This has important implications for comparing results across studies and for the practice of importing parameter values across studies.

There are several dimensions along which it will be important to extend the analysis carried out here. For example, in this paper we have only analyzed the evolution of expenditure shares and prices in one country – the postwar US. It is also of interest to extend this analysis to a larger set of countries, in particular to situations which feature a larger range of real incomes. This will be useful in assessing the extent to which one can account for the process of structural transformation with stable preferences.

REFERENCES

Acemoglu, Daron, and Veronica Guerrieri. 2008. "Capital Deepening and Non–Balanced Economic Growth." *Journal of Political Economy*, 116: 467–498.

Aguiar, Mark, and Eric Hurst. 2007. "Measuring Leisure: The Allocation of Time Over Five Decades." *Quarterly Journal of Economics*, 122: 969–1006.

Bah, El–Hadj. 2008. "Structural Transformation in Developed and Developing Countries." Arizona State University. Manuscript, Tempe, AZ.

Barnett, William A., and Apostolos Serletis. 2008. "Consumer Preferences and Demand Systems." *Journal of Econometrics*, 147: 210–224.

Baumol, William J. 1967. "Macroeconomics of Unbalanced Growth: The Anatomy of the Urban Crisis." *American Economic Review*, 57: 415–426.

Blundell, Richard. 1988. "Consumer Behaviour: Theory and Evidence – A Survey." *Economic Journal*, 98: 16–65.

Boskin, Michael J., Ellen R. Dulberger, Robert J. Gordon, Zvi Griliches, and Dale Jorgenson. 1996. "Toward A More Accurate Measure Of The Cost Of Living." Working Paper, Washington, DC. FINAL REPORT to the Senate Finance Committee from the Advisory Commission To Study The Consumer Price Index.

Buera, Francisco J., and Joseph P. Kaboski. 2009. "Can Traditional Theories of Structural Change Fit The Data?" *Journal of the European Economic Association*, 7: 469–477.

Burnham, Kenneth P., and David R. Anderson. 2002. *Model Selection and Multimodel Inference: A Practical Information–theoretic Approach.* New York, Berlin: Springer Verlag.

Caselli, Francesco, and Wilbur John Coleman. 2001. "The U.S. Structural Transformation and Regional Convergence: A Reinterpretation." *Journal of Political Economy*, 109: 584–616.

Deaton, Angus. 1986. "Demand Analysis." In *Handbook of Econometrics*. Vol. 3, ed. Zvi Griliches and Michael D. Intriligator, Chapter 10, 1767–1839. Amsterdam and New York: North Holland.

Deaton, Angus, and John Muellbauer. 1980. "An Almost Ideal Demand System." *American Economic Review*, 70: 312–326.

Duarte, Margarida, and Diego Restuccia. 2010. "The Role of the Structural Transformation in Aggregate Productivity." *Quarterly Journal of Economics*, 125: 129–173.

Echevarria, Cristina. 1997. "Changes in Sectoral Composition Associated with Economic Growth." *International Economic Review*, 38: 431–452.

Foellmi, Reto, and Josef Zweimller. 2008. "Structural Change, Engel's Consumption Cycles, and Kaldor's Facts of Economic Growth." *Journal of Monetary Economics*, 55: 1317–1328.

Fuchs, Victor. 1968. *The Service Economy.* New York: Columbia University Press.

Geary, Roy C. 1950-1951. "A Note on A Constant–Utility Index of the Cost of Living." *Review of Economic Studies*, 18: 65–66.

Gollin, Douglas, Stephen L. Parente, and Richard Rogerson. 2002. "The Role of Agriculture in Development." *American Economic Review, Papers and Proceedings*, 92: 160–164.

Gollin, Douglas, Stephen L. Parente, and Richard Rogerson. 2006. "The Food Problem and the Evolution of International Income Levels." *Journal of Monetary Economics*, 54: 1230–1255.

Greene, William H. 2011. *Econometric Analysis.* . 7 ed., Upper Saddle River, New Jersey: Prentice Hall.

Herrendorf, Berthold, and Ákos Valentinyi. 2012. "Which Sectors Make Poor Countries so Unproductive?" *Journal of the European Economic Association*, 10: 323–341.

Herrendorf, Berthold, Christopher Herrington, and Ákos Valentinyi. 2012. "Sectoral Technology and Structural Transformation." Arizona State University Manuscript.

Herrendorf, Berthold, James Schmitz Jr, and Arilton Teixeira. 2012. "The Role of Transportation in U.S. Economic Development: 1840-1860." *International Economic Review*, 53: 693–715.

Herrendorf, Berthold, Richard Rogerson, and Ákos Valentinyi. 2013. "Growth and Structural Transformation." Forthcoming In *Handbook of Economic Growth*. Vol. 2, ed. Philippe Aghion and Steven Durlauf. Elsevier.

Kongsamut, Piyabha, Sergio Rebelo, and Danyang Xie. 2001. "Beyond Balanced Growth." *Review of Economic Studies*, 68: 869–882.

Kuznets, Simon. 1966. *Modern Economic Growth.* New Haven:Yale University Press.

Laitner, John. 2000. "Structural Change and Economic Growth." *Review of Economic Studies*, 67: 545–561.

Landefeld, J. Steven, and Robert P. Parker. 1997. "BEA's Chain Indexes, Time Series, and Measures of Long Term Economic Growth." In *Survey of Current Business*. Bureau of Economic Analysis.

Messina, Julian. 2006. "The Role of Product Market Regulations in the Process of Structural Change." *European Economic Review*, 50: 1863–1890.

Ngai, L. Rachel, and Chrisopher A. Pissarides. 2007. "Structural Change in a Multi-sector Model of Growth." *American Economic Review*, 97: 429–443.

Ngai, L. Rachel, and Chrisopher A. Pissarides. 2008. "Trends in Hours and Economic Growth." *Review of Economic Dynamics*, 11: 239–256.

Pollak, Robert, and Terence J. Wales. 1969. "Estimation of the Linear Expenditure System." *Econometrica*, 37: 611–628.

Ramey, Valery A., and Neville Francis. 2009. "A Century of Work and Leisure." *American Economic Journal: Macroeconomics*, 1: 189–224.

Rogerson, Richard. 2008. "Structural Transformation and the Deterioration of European Labor Market Outcomes." *Journal of Political Economy*, 116: 235–259.

Stone, Richard. 1954. "Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand." *Economic Journal*, 64: 511–527.

Valentinyi, Ákos, and Berthold Herrendorf. 2008. "Measuring Factor Income Shares at the Sectoral Level." *Review of Economic Dynamics*, 11: 820–835.

Whelan, Karl. 2002. "A Guide to U.S. Chain–Aggregated NIPA Data." *Review of Income and Wealth*, 48: 217–233.

Appendix

Data Sources

All data are in per capita terms and for the U.S. during 1947–2010.

We calculate a per capita quantity by dividing the total quantity by the population size. We take the population size from NIPA Table 7.1: "Selected Per Capita Product and Income Series in Current and Chained Dollars".

The construction of final consumption expenditure data is based on standard NIPA tables from the BEA. We use the most recent NIPA data released in August 2009 which incorporates the last comprehensive revision. In particular, we use data from the following tables:

- Table 2.4.3: "Real Personal Consumption Expenditures by Type of Product, Quantity Indexes"; Table 2.4.5: "Personal Consumption Expenditures by Type of Product"; .

- Table 3.10.3: "Real Government Consumption Expenditures and General Government Gross Output, Quantity Indexes"; Table 3.10.5: "Government Consumption Expenditures and General Government Gross Output"

The construction of total value added data by sector is based on the Annual Industry Accounts, which contain current dollar value added and quantity indices by industry based on chain weighted methods. The value added by industry data is consistent with the NAICS for the entire period 1947–2010.[25]

The construction of consumption value added (as opposed to production value added) is based on two main data sources: the annual expenditure data described above and the total requirement matrices from the IO Tables. In the next subsection, we describe in detail how these two data sources are combined to obtain consumption value added. Here we just describe the exact data sources. There are benchmark IO Tables and annual IO Tables. Benchmark IO Tables are available for 1947, 1958, 1963, 1967, 1972, 1977, 1982, 1987, 1992, 1997 and 2002.[26] Annual IO Tables are available for each year during the period 1998–2010.[27] An important additional data source are the so called "Bridge Tables for Personal Consumption Expenditure", which are available for the 1997 and 2002 benchmark IO Tables. Bridge Tables link IO Tables with the standard expenditure data of the BEA. In particular, they report how personal consumption expenditure in the IO Tables are related to those in the BEA expenditure tables. If we don't have IO Tables for a particular year, then we use linear interpolation between the years for which IO Tables are available.

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[25]http://www.bea.gov//industry/zip/AllTables.zip
[26]http://www.bea.gov/industry/io_benchmark.htm
[27]http://www.bea.gov/industry/io_annual.htm

Sector Assignment

When we use final consumption expenditure data, the three sectors contain the following BEA *commodities*:

- Agriculture: "food and beverages purchased for off-premises consumption"

- Manufacturing: "durable goods"; "nondurable goods" excluding "food and beverages purchased for off-premises consumption"

- Services: "services"; "government consumption expenditure"

When we use value added data, the three sectors contain the following BEA *industries*:

- Agriculture: "farms"; "forestry, fishing, and related activities"

- Manufacturing: "construction"; "manufacturing"; "mining"

- Services: all other industries including "government industries"