CAN TRADITIONAL THEORIES OF STRUCTURAL CHANGE FIT THE DATA?

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Abstract
Two traditional explanations for structural changes are sector-biased technological progress and non-homothetic preferences. This paper integrates both into an otherwise standard growth model and quantitatively evaluates them vis-a-vis time series. The exercise identifies a set of puzzles for standard theories: (i) the model cannot account for the steep decline in manufacturing and rise in services in the later data; (ii) the standard model requires implausibly low elasticity of substitution across goods to match the consumption and output data; and (iii) the behavior of consumption and output shares differs significantly from that of employment shares. We argue that models that incorporate home production, sector-specific factor distortions, and differences across sectors in the accumulation of human capital are promising avenues to amend the standard models. (JEL: O11, O14, O41)

1. Introduction

Structural change has long been considered an integral part of the process of growth and development. The traditional literature dating back to the 19th century conjectured that either Engel's law (e.g., Engel 1895; Houthakker 1957), biased productivity growth (e.g., Baumol 1967), or some combination account for sectoral trends in output and labor across agriculture, industry, and services.[1] Two recent works have formalized and extended these ideas to reconcile structural change with standard growth models consistent with otherwise balanced growth. Kongsamut et al. (2001) and Ngai and Pissarides (2007) give particular models in which non-homothetic preferences and biased productivity growth, respectively, yield structural change along with constant growth rates of output and consumption.

Theoretically, we show that these balanced growth predictions cannot be reconciled in an integrated model where both non-homothetic preferences and biased

Acknowledgments: We would like to thank Reto Föllmi, Kiminori Matsuyama, and Joseph Zweimüller for comments and suggestions.

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1. See Matsuyama (2008) for a recent review of this literature.

Journal of the European Economic Association April–May 2009 7(2–3):469–477

productivity growth affect the structure of production. Nonetheless, the exercise of this paper is to combine these two explanations to see whether such a model can do reasonably well quantitatively in matching the data. We also quantify the relative merits of demand and supply explanations. The exercise highlights important shortcomings of traditional explanations, including an inability to account for observed sectoral movements, a need for an unrealistic elasticity of substitution, and a discrepancy in the data between trends in sectoral labor shares and trends in sectoral output shares. We show that models incorporating frictions and/or human capital may be important in reconciling these puzzles, and we conjecture that considering higher levels of disaggregation and the home production margin may also be fruitful.

2. Model

We study a general framework integrating non-homothetic preferences and biased productivity/price movements that aggregates into a standard neoclassical growth model. We then integrate distortions and average human capital levels that potentially differ across sectors.

2.1. Preferences

The representative agent has preferences over sequences of consumption vectors $c = \{\{c_{it}\}_{i=a,m,s}\}_{t=0}^{\infty}$ represented by the following utility function

$$U(c) = \sum_{t=0}^{\infty} \beta^t v(c_{at}, c_{mt}, c_{st})^{1-\sigma}/(1-\sigma), \tag{1}$$

where

$$v(c_{at}, c_{mt}, c_{st}) = \left[\sum_{i=a,m,s} \gamma_i (c_{it} - \bar{c}_i)^{(\varepsilon-1)/\varepsilon} \right]^{\varepsilon/(\varepsilon-1)}.$$

CONSUMER'S PROBLEM. Given sequences of prices, $\{p_{it}\}_{i=a,m,s}$, w_t, and R_t, $t = 0, 1, \ldots$, and human capital h, the representative agent chooses sequences of consumption vectors $\{\{c_{it}\}_{i=a,m,s}\}_{t=0}^{\infty}$ and capital accumulation I_t, k_t to maximize equation (1) subject to a standard budget constraint,

$$\sum_{i=a,m,s} p_{it} c_{it} + p_{mt} I_t \leq R_t k_t + w_t h,$$

and the law of motion for capital,

$$k_{t+1} = (1-\delta)k_t + I_t.$$

To show its relationship to the neoclassical growth model, it is useful to rewrite the representative agent's problem as the following alternative program.

EQUIVALENT CONSUMER'S PROBLEM. Given sequences of prices, $\{p_{it}\}_{i=a,m,s}$, w_t, and $R_t, t = 0, 1, \ldots$, the representative agent chooses sequences of consumption expenditures net of the value of consumption requirements, c_t, and capital accumulation I_t, k_t to maximize

$$\sum_{t=0}^{\infty} \hat{\beta}_t c_t^{1-\sigma}/(1-\sigma)$$

subject to a standard budget constraint

$$p_{mt}c_t + p_{mt}I_t \leq R_t k_t + w_t h - \sum_{i=a,m,s} p_{it}\bar{c}_i$$

and the law of motion for capital,

$$k_{t+1} = (1-\delta)k_t + I_t,$$

where

$$c_t = \sum_i p_i c_{it} - \sum_i p_i \bar{c}_{it}$$

and

$$\hat{\beta}_t = \beta^t \left[\sum_i \left(\frac{\gamma_i}{\gamma_m} \right)^{\varepsilon} \left(\frac{p_{it}}{p_{mt}} \right)^{1-\varepsilon} \right]^{(1-\sigma)/(\varepsilon-1)}.$$

The following proposition characterizes the set of parameter values for which structural change is consistent with balanced growth.

PROPOSITION 1. *In this economy structural change is consistent with balanced growth if and only if*

(a) $(\bar{c}_a, \bar{c}_m, \bar{c}_s) \neq 0$, *and* $\sum_i p_{it}\bar{c}_i = 0$ *for all t (Kongsamut et al. 2001), or*
(b) $p_{it+1}/p_{it} \neq p_{i't+1}/p_{i't}$ *for some* $i \neq i'$, $\sigma = 1$ *and* $\sum_i p_{it}\bar{c}_i = 0$ *for all t (Ngai and Pissarides 2007).*

The consumer's problem is already quite insightful. Proposition 1 states that the non-homothetic preference story of Kongsamut, Rebelo, and Xie (2001) and the biased productivity growth story of Ngai and Pissarides (2007) are special cases of our model that lead to structural change and balanced growth. Interestingly, they are also mutually exclusive cases, because (b) requires that $\bar{c}_i = 0$ for all sectors with changing relative prices.

Finally, in both special cases $c_t = \sum_i p_i c_{it}$ and $\hat{\beta}_t = \beta^t$, so that both models reduce to the standard growth model. That is, although both models produce balanced growth, they also produce structural change that is not particularly important to overall welfare. Structural change is of secondary interest, because a simple aggregate model tells us all we need to know about growth.

2.2. Technologies

In order to get predictions for output and labor in this section we specify a model of technologies and policies.

Sector i's output is produced with a standard Cobb–Douglas technology

$$Y_i = A_i K_i^{\alpha} (h_i L_i)^{1-\alpha},$$

where A_i is the total factor productivity (TFP), K_i the amount of capital used, L_i the workforce employed, and h_i the average human capital. We assume that sectors differ in their TFP (A_i) and the average human capital of their workforce (h_i). We assume that the three broad sectors have similar factor intensity (α), which is consistent with data (see Herrendorf and Valentinyi 2007a).

We consider a competitive equilibrium of this economy, in which capital and the workforce are endogenously allocated across sectors. We allow firms to face sector-specific distortions τ_k^i and τ_l^i to capital and labor, respectively. Such distortions potentially give structural change first-order importance, because they allow for aggregate output gains from reallocation.

FIRM'S PROBLEM. Firms in sector i choose capital and labor inputs to maximize profits:

$$\max_{k_i, h_i, l_i} \; p_i A_i K_i^{\alpha} (h_i L_i)^{1-\alpha} - \left(1 + \tau_k^i\right) R K_i - \left(1 + \tau_l^i\right) w h_i L_i.$$

The following two propositions follow from the necessary conditions of the firm's problem.

PROPOSITION 2. *The model implies the following relationship between values added shares* (y_i)*, labor shares* (l_i)*, the average human capital* (h_i) *and labor distortions* (τ_l^i)*:*

$$y_i = \frac{p_i Y_i}{\sum_j p_j Y_j} = \frac{h_i \left(1 + \tau_l^i\right) l_i}{\sum_j h_j \left(1 + \tau_l^j\right) l_j},$$

where $l_i = L_i / (\sum_j L_j)$.

In the absence of human capital differences and differential distortions (i.e., $\tau_l^i = \tau_l^j$ and $h_i = h_j$), value-added shares and labor shares are equal. To the extent that the two deviate, human capital differences and distortions are quantitatively important, and raw labor shares may be less meaningful.

PROPOSITION 3. *The model implies the following relationship between relative prices (p_i), TFP (A_i) and input distortions (τ_k^i, τ_l^i) across two sectors $i \neq i'$:*

$$\frac{p_i}{p_{i'}} = \frac{A_{i'}}{A_i}\left(\frac{1+\tau_k^i}{1+\tau_k^{i'}}\right)^{\alpha}\left(\frac{1+\tau_l^i}{1+\tau_l^{i'}}\right)^{1-\alpha}.$$

Here we show the link between relative prices and relative productivities and distortions. Again, in the absence of distortions relative prices reflect relative productivities.

3. Structural Change: U.S. 1870–2000

In order to evaluate the roles of non-homotheticities and biased productivity, we set all distortions to zero, and equate human capital levels across sectors. We calibrate the model to minimize the (unweighted) sum of squared errors between the model and the time series data on output, current-price value-added shares, and relative prices for the U.S. from 1870–2000.

Figure 1 shows how the calibrated model's fit of the sectoral value-added share data. The solid line represents the calibrated of the model, and the dots represent the data. The model calibrates a substantial subsistence requirement for agriculture ($\bar{c}_a = 0.0048$), a sizable basic endowment of services ($\bar{c}_s = 0.0062$), and no consumption requirement for manufacturing.[2] We calibrate an elasticity of substitution of 0.5.[3]

Although the model does reasonably well for agriculture, with the subsistence requirement playing the central role, the fit is poor for industry and services. The model fails to match the sharper increase in services and decline in manufacturing after 1960. A major problem is that the relative price of services to industry was rising during this period but at a slower rate than the relative shares. Thus, in this later period, both the relative quantity and relative price of services were rising relative to industry. Explaining this would require a large, delayed income effect

2. The consumption requirement of agricultural goods amounts to 16% of per capita income in 1860, and the endowment of services (negative consumption requirement) amounts to 12% of 1860 per capita income.

3. If unconstrained, the best fit of the model would require Leontieff preferences ($\varepsilon \to 0$). Because the fit of the model does not improve substantially, we choose a low but more reasonable value for this parameter.

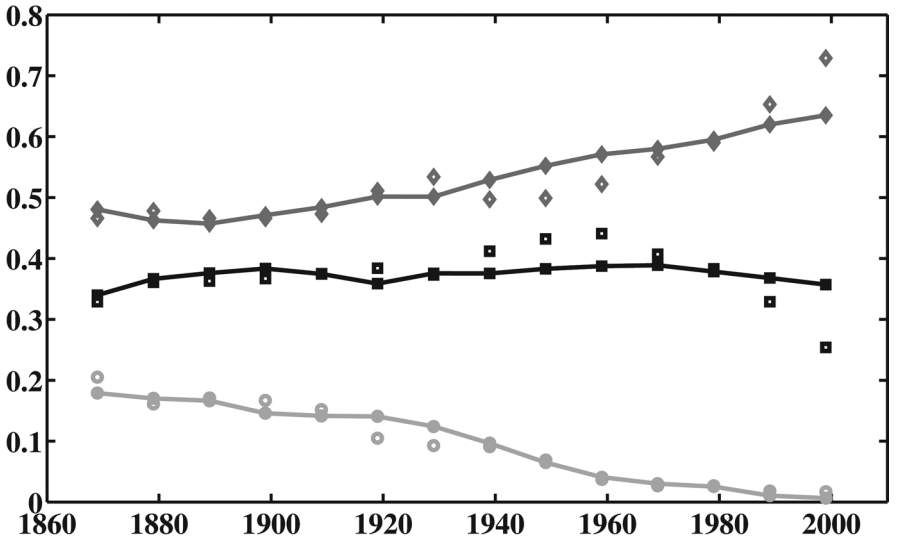

FIGURE 1. Evolution of value-added shares: agriculture (data: circles; model: line-circles), manufacturing (squares; line-squares), services (diamonds; line-diamonds). United States, 1860–2000.

toward services. This is not possible with the Stone–Geary preferences, where the endowments and subsistence requirements are most important at low levels of income. With little income effect late in the sample, the model does what it can with substitution. The fact that the relative share of services is rising faster than the relative price of services would require (non-quasiconcave) preferences in which households substitute toward the more expensive good. The best the model could do is calibrate Leontieff preferences.

Figure 2 notes another important shortcoming in the model. Panel (a) shows the large deviation between value-added shares and labor shares, especially early in development. Recall that given Proposition 2, the standard model cannot explain this without sectoral differences in human capital or factor distortions. Panel (b) plots the implied relative labor distortions or, equivalently, relative human capital levels, which again are larger earlier in development. These distortions could indicate either a barrier into services and manufacturing and out of agriculture, larger human capital levels in services and manufacturing, lower human capital levels in agriculture, or some combination of the two.

Caselli and Coleman (2001) emphasize a trend in the U.S. between agriculture and non-agriculture using the wedge in wages rather than output per worker. They model the initial gap as the result of frictions in obtaining education necessary for non-agriculture, and posit declining educational costs to explain the secular

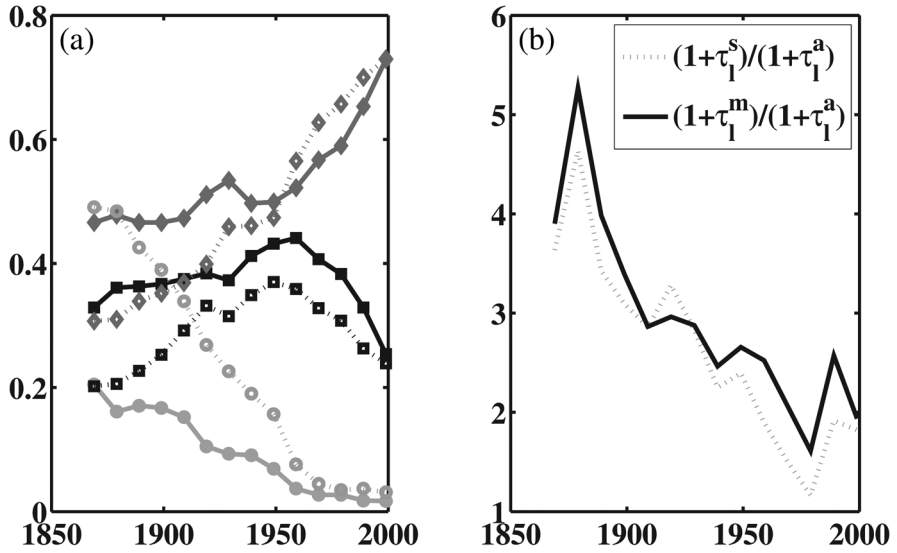

FIGURE 2. (a) Evolution of value-added shares (solid) vs. employment shares (dashed): agriculture (circles), manufacturing (squares), services (diamonds). United States, 1860–2000. (b) Implied relative human capital and sectoral factor distortions: manufacturing (h_m/h_a, $(1+\tau_l^m)/(1+\tau_l^a)$, solid) and services ($h_s/h_a$, $(1+\tau_l^s)/(1+\tau_l^a)$, dashed).

convergence. Hence, their model has aspects of both the distortions and human capital story, but it does not distinguish manufacturing and services.

4. Conclusions

We have highlighted shortcomings of traditional explanations of structural change. These puzzles call for new directions in structural change, many of which are already being pursued in the literature of New Structural Change. Models with sequential non-homotheticities (e.g., Matsuyama 2002; Foellmi and Zweimueller 2006, 2009; Buera and Kaboski 2007, 2008), higher levels of disaggregation (e.g., Herrendorf and Valentinyi 2007b; Acemoglu and Guerrieri 2008), and home production (e.g., Buera and Kaboski 2007, 2008; Rogerson 2008) may better match the observed data on value-added shares. Models that incorporate the role of human capital (Buera and Kaboski 2008) and/or sector specific distortions (Herrendorf and Valentinyi 2007b; Buera, Kaboski, and Shin 2008, Restuccia, Yang, and Zhao 2008) may be fruitful in explaining the divergence between labor and value-added shares. Empirical work is needed to distinguish between the roles of sector specific distortions and relative human capital levels by exploring data on labor income shares, although a theoretical justification is also needed

to explain convergence of distortions and/or human capital levels over development. Research linking structural change to distortions, human capital, and home production may also give a more fundamental role of structural change, linking it to first-order effects on output, inequality, and organization of the family. Finally, an important avenue for further research is to imbed structural change into open economy models (Fieler 2007; Matsuyama 2009).

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