A Three-Sector Model of Structural Transformation and Economic Development

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Differences in total factor productivity (TFP) are the dominant source of the large variation of income across countries. This paper seeks to understand which sectors account for the aggregate TFP gap between rich and poor countries. I propose a new approach for estimating sectoral TFP using panel data on sectoral employment shares and GDP per capita. The approach builds a three-sector model of structural transformation and uses it to infer time paths of sectoral TFP consistent with the reallocation of labor between sectors and GDP per capita growth of a set of developing countries over a 40-year period. I find that relative to the US, developing countries are the least productive in agriculture, followed by services and then manufacturing. The findings are consistent with the evidence from micro data and the approach has the novelty to measure sectoral TFPs over the long term.

Keywords: Productivity, Sectoral TFP, Structural Transformation, Economic growth, Economic Development

JEL Classification: O14, O41, O47

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1. Introduction

Income differences across countries are large: income per capita for the US in 2000 was about 30 times the average for the least developed countries. Growth accounting exercises point to differences in total factor productivity (TFP) as the biggest source of cross-country income differences[1]. In this paper, I ask which economic sectors account for this TFP gap. The answer to this question is important for two reasons. First, it can help us construct theories for explaining the low productivity in developing countries. Second, it can be useful for formulating policy recommendations.

The key challenge for measuring sectoral TFP in developing countries is data availability. A simple sectoral growth accounting exercise requires comparable data for sectoral value added in constant prices, sectoral capital stock and sectoral employment. Only data for sectoral employment is available for developing countries. This data limitation has led researchers to use indirect methods for estimating sectoral TFPs. The existing literature uses data on cross-section prices in a multi-sector growth model to infer sectoral relative TFPs[2].

A key contribution of this paper is to show how data on structural transformation, i.e., the reallocation of labor across sectors as an economy develops, can be used to uncover sectoral TFP differences. Kuznets included the process of structural transformation as one of six stylized facts of economic development. He found that developed countries all followed a similar process. However, as Bah (2009) documents, many developing countries are following processes that are very different from the path of developed countries. It is then natural to think that cross-country differences in the process of structural transformation provide information about cross-country differences in aggregate income and productivity.

Specifically, I extend the neoclassical growth model to include three sectors (agriculture, manufacturing and services) and use it to infer sectoral TFP time series consistent with GDP per capita growth and structural transformation over a 40-year period. Follow-

[1] Examples include Hall and Jones (1999), Prescott (1998), Klenow and Rodriguez-Clare (1997), Parente and Prescott (1994, 2000), Hendricks (2002), Caselli (2005).

[2] See Hsieh and Klenow (2007) and Herrendorf and Valentinyi (2007).

ing Rogerson (2008), the model incorporates two channels that drive labor reallocation between the sectors associated with structural transformation: income and substitution effects. First, non-homothetic preferences through a subsistence requirement drive labor out of agriculture[3]. Second, a TFP growth differential and the elasticity of substitution between the manufacturing and service sectors drive the reallocation of labor between those two sectors[4].

I calibrate the model to match the structural transformation and per capita GDP growth for the US over the period 1950-2000. I then use the calibrated model to infer time paths of sectoral TFP that are consistent with the structural transformation and economic development experiences of three developing countries with very different income levels: Cameroon, Brazil and Korea[5].

In this exercise, I assume that preferences are similar across countries but allow all sectoral TFPs to vary. I show that given data on sectoral employment and aggregate GDP per capita, the model can be used to infer the time series for sectoral TFPs. The actual implementation of the approach is somewhat complex because of the dynamics associated with capital accumulation, but at a heuristic level, the approach works as follows. Given the calibrated preference parameters, observed employment in agriculture determines the level of agricultural TFP. Relative employment in manufacturing and services determines the relative TFPs of those two sectors. Finally, aggregate GDP per capita determines the levels of TFP in manufacturing and services.

Using this approach, I find that relative to the US, developing countries are the least productive in agriculture, followed by services and then manufacturing. Korea had high TFP growth in all three sectors and it was catching up to the US during the 40-year period. Relative to the US, Cameroon and Brazil did not improve their productivities in agriculture and fell behind in services. In manufacturing, Cameroon lost ground to the US while Brazil experienced a modest catch-up especially between 1960 and 1980. I also use my inferred aggregate capital stock from the model to conduct a simple growth accounting

[3]Authors using this feature include: Echevarria (1997), Kongsamut et al. (2001), Laitner (2000), and Gollin et al. (2002, 2007).

[4]This feature is used by Beaumol (1967); Ngai and Pissarides (2007).

[5]While Korea is no longer a developing country, it was for the most part of the period considered here.

exercise for Korea. I find, similarly to the literature (e.g (Young, 1995), (Bosworth and Collins, 1996)), that capital accumulation played the primary role, followed by TFP and labor[6].

My findings on relative sectoral productivity are consistent with the available evidence from micro and producer data. The finding that developing countries are the least productive in agriculture is not new. It is a robust finding of the development literature that compares productivity of agriculture and non-agriculture[7]. There is also a vast literature that estimates agricultural production functions across countries and try to find the determinants of low productivity for developing countries[8].

Between manufacturing and services, the micro data collected by the McKinsey Global Institute and analyzed by Bailey and Solow (2001) and Baily et al. (2005) show that relative to the US, developed and developing countries are less productive in services than in manufacturing. This sectoral ranking holds for both labor productivity and TFP. For instance, Baily et al. (2005) finds that while Turkey's labor productivity is at 66% of the US in manufacturing, it is only at 33% in services. Duarte and Restuccia (2010) used a similar three-sector model to examine sectoral labor productivity for a group of developed and developing countries. They also find that relative to the US other countries are the least productive in agriculture and services. In contrast, Herrendorf and Valentinyi (2007) uses cross-section relative prices from expenditure data from the Penn World Table (PWT) and finds that relative TFP differences in services are small compared to consumption goods, construction and equipment goods sectors.

This paper is related to the large literature studying income differences across countries. Closely related, are a number of papers that focus on the sectoral composition of output to study aggregate outcomes[9]. A number of papers emphasize the role of structural transformation in the development and growth experiences of countries. Gollin et al. (2002, 2007) show the importance of agriculture in the delaying the start of modern

[6]In this exercise, I don't include human capital which would have the effect of decreasing the role of TFP and increasing that of labor.

[7]See Kuznets (1971), Gollin et al. (2002, 2007), Young (2008), Restuccia et al. (2008).

[8]Examples include Hayami and Ruttan (1970, 1985) and Mundlank (2001).

[9] See for instance Young (2008), Restuccia et al. (2008), Caselli (2005), Adamopoulos and Akyol (2009), Chanda and Dalgaard (2005), Vollrath (2009)

economic growth. Duarte and Restuccia (2010) has a model similar to mine but focuses on labor productivity to explain growth episodes and disasters in a number of countries. Hsieh and Klenow (2007) and Herrendorf and Valentinyi (2007) also use general equilibrium models to infer sectoral TFPs but instead use cross-section price data from the PWT. Hsieh and Klenow (2007) focuses on sectors producing consumption and investment goods while Herrendorf and Valentinyi (2007) include services, consumption goods, construction and equipment goods.

The rest of the paper is organized as follows. Section 2 describes the model and characterizes the competitive equilibrium. Section 3 calibrates the model to the US economy. Section 4 applies the model to a sample of developing countries and find their time paths of sectoral TFP. Section 5 discusses the findings and section 6 concludes.

2. A Three-Sector Model of Structural Transformation

This section develops a three-sector model of structural transformation, which is characterized as follows. Early in the development process, the majority of the labor force is engaged in food production. As food output rises, labor moves from agriculture into manufacturing and services. This is the first phase of structural transformation. In the second phase, labor moves from agriculture and manufacturing into services. This process of structural transformation has been followed by current developed countries but as Bah (2009) documents, many developing countries are following processes that are very distinct from the above process. The share of services in output is high at relatively low income per capita in many developing countries in Africa and Latin America. This is not the case for Asian countries that are mostly following the path of developed countries. The model developed here will emphasize differential in sectoral productivity growth as the main feature explaining differences in structural transformation processes. The model will be calibrated to match the growth and structural transformation of the US economy for the period 1950-2000. In the next section, the calibrated model will be used to infer sectoral TFPs for a select of developing countries.

2.1. Model

At each period, the economy has three sectors that produce each one good: agriculture, manufacturing and services. A key for the model is to replicate the labor reallocation across different sectors of the economy. Following Rogerson (2008), the model has two features to achieve this outcome: non-homothetic preferences and technological growth differential across sectors. If income elasticities are not all unitary, then resources are reallocated across sectors as the income increases. Examples emphasizing this feature include Echevarria (1997), Kongsamut et al. (2001), Laitner (2000), and Gollin et al. (2002, 2007). Technological growth differential and non-unitary elasticities of substitution across goods lead to resource reallocation across sectors. This feature has been emphasized by Beaumol (1967) and Ngai and Pissarides (2007).

To simplify the analysis, I assume closed economies, which seems reasonable given the structure of my model [10].

2.1.1. Preferences

There is a representative household who lives forever. For simplicity, I assume the size of the household is constant. The household supplies labor to the three sectors and uses its wage compensation to consume three final goods: an agricultural good, a manufactured good and services. Lifetime utility is given by:

$$\sum_{t=0}^{\infty} \beta^t U(\Phi_t, A_t), \quad \beta \in (0,1) \tag{1}$$

Instantaneous utility is defined over the agricultural good (A_t) and a composite consumption good (Φ_t) which is derived from the manufacturing and service sectors. The instantaneous utility is given by:

$$\log(\Phi_t) + V(A_t) \tag{2}$$

[10] Gollin et al. (2007) documents that developing countries engage in little trade in food products. While, the assumption maybe strong for some countries, like Korea which used export-led growth to develop, allowing for trade will strengthen my result for such a country.

$V(A_t)$ is non-homothetic and is given by:

$$V(A_t) = \begin{cases} -\infty & \text{if} \quad A_t < \overline{A} \\ min(A_t, \overline{A}) & \text{if} \quad A_t \geq \overline{A} \end{cases} \tag{3}$$

This specification assumes that there is a subsistence level $\overline{A}$ below which the household cannot survive. This feature has been shown to be quantitatively important for driving labor out of agriculture[11]. While the specification seems to simplify the analysis of the model, we will see later that it also describes the data reasonably well.

The composite good is a CES aggregate of the manufactured good (M_t) and services (S_t)[12].

$$\Phi_t = \left(\lambda M_t^{\frac{\epsilon-1}{\epsilon}} + (1-\lambda) S_t^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}, \quad \epsilon \in (0,1) \quad \text{and} \quad \lambda \in (0,1) \tag{4}$$

2.1.2. Endowments

In each period the household is endowed with one unit of time, all of which is devoted to work. Also, the household is endowed with initial capital stock at time 0 and the total land for the economy. I normalize the size of land to 1 and assume that land does not depreciate.

2.1.3. Technologies

Agriculture: My specification for agriculture is very basic. The agricultural good is produced using a Cobb-Douglas production function with labor (N) and land (L) as the only inputs. This formulation assumes that capital and intermediate inputs are not used in the production technology. Quantitatively, the effects of capital and the use of intermediate inputs are implicitly captured by agricultural TFP. Given that different countries have different intensities in their use of capital and intermediate inputs in agriculture, the estimated relative TFP may be biased. However, it is unlikely that

[11] See Echevarria (1997), Kongsamut et al. (2001), Laitner (2000), and Gollin et al. (2002, 2007)

[12] Here, I abstract for services produced at home that Rogerson (2008) finds important for explaining why European countries substitute away from market services in the face of higher taxes.

this will overturn the finding that agriculture is relatively the least productive sector in developing countries which is a very robust finding of the development literature.

The agricultural good is only used for consumption so the resource constraint is given by:

$$A_t = A_{at} N_{at}^{\alpha} L_t^{1-\alpha} \tag{5}$$

where the TFP evolves according to: $A_{at} = A_a(1+\gamma_{at})^t$. The TFP parameter A_a and γ_{at} in the equation above are assumed to be country specific. There are many sources of cross-country differences in agricultural efficiency. One source is government policies and institutions that have an impact on agricultural activity[13]. As an example, it has been shown that marketing boards, present in many African countries until the 1990s, were inhibiting the development of the agriculture sector[14]. Another source of variation is the quality of land available per person and the climate(s) prevailing in the country. For example, a variety of seed developed for one region will not necessarily be suited for another.

Manufacturing and Services: The manufacturing and service sectors produce output using standard Cobb-Douglas production functions with capital and labor as inputs. I assume identical capital shares in both sectors which is consistent with estimates by Herrendorf and Valentinyi (2008) for the US economy[15]. The manufacturing sector's output is used for consumption (M_t) in the composite good and investment (X_t). The manufacturing sector resource constraint is:

$$M_t + X_t = A_{mt} K_{mt}^{\theta} N_{mt}^{1-\theta} \tag{6}$$

where TFP evolves as: $A_{mt} = A_m(1+\gamma_{mt})^t$. The law of motion of the aggregate capital

[13]Restuccia et al. (2008) finds that the lack of use of intermediate inputs and distortions in the labor market explain a big part of the large disparity in agricultural productivity between rich and poor countries

[14]These are governmental institutions that buy export crops from farmers at fixed low prices, then resell them abroad at world prices. See Sachs and Warner (1995), Wacziarg and Welch (2008) for details.

[15]Their estimates are 0.33 for manufacturing and 0.34 for services. This assumption will lead manufacturing and services to be aggregated in one sector with aggregate capital share identical to the sectoral one. I will also assume that developing countries have the same capital as the US. This is consistent with the finding by Gollin (2002) that capital shares are similar across countries at the aggregate level.

stock (K_t) in the economy is given by:

$$K_{t+1} = (1-\delta)K_t + X_t \tag{7}$$

where δ is the depreciation rate.

The output of the service sector is only used for consumption through the composite good. Therefore, resource constraint for the service sector is given by:

$$S_t = A_{st}K_{st}^{\theta}N_{st}^{1-\theta} \tag{8}$$

where TFP evolves as: $A_{st} = A_s(1+\gamma_{st})^t$.

In the equations above, the TFP parameters A_m, A_s, γ_{mt} and γ_{st} are also assumed to be country specific. Recovering how these differ across countries is the main contribution of this paper. Again, a country's institutions and policies affect its productivity in these economic activities.

2.2. Equilibrium

In this section, I describe how to solve for the competitive equilibrium of the model economy from the start of structural transformation[16]. Note that there are no distortions in the economy, therefore the equilibrium allocations can be obtained by solving a social planner's problem[17]. Let T be the first period in which the economy can move labor out of agriculture. From period T on, a social planner chooses the allocations $(K_t, K_{mt}, K_{st}, N_{at}, N_{mt}, N_{st}, S_t, L_t)$ to solve the following maximization problem:

$$\max \sum_{t=T}^{\infty} \beta^{t-T}(\log(\Phi_t) + V(A_t))$$

$s.t$

$$\Phi_t = \left(\lambda M_t^{\frac{\epsilon-1}{\epsilon}} + (1-\lambda)S_t^{\frac{\epsilon-1}{\epsilon}}\right)^{\frac{\epsilon}{\epsilon-1}}$$

[16]The definition of competitive equilibrium is standard so I do not reproduce it here.

[17]There is vast body of the development literature that argues that distortions in both factors and output markets are a fundamental obstacle to development. This paper abstracts from that debate.

$$\overline{A} = A_{at} N_{at}^{\alpha} L_t^{1-\alpha}$$

$$S_t = A_{st} K_{st}^{\theta} N_{st}^{1-\theta}$$

$$M_t + X_t = A_{mt} K_{mt}^{\theta} N_{mt}^{1-\theta}$$

$$K_{t+1} = (1-\delta) K_t + X_t$$

$$K_{mt} + K_{st} = K_t$$

$$N_{at} + N_{mt} + N_{st} = 1$$

In what follows, I develop a solution method similar to that for the one sector growth model. Recalling that we normalized land to be one, and given the preferences over food consumption, we can easily solve for employment in agriculture; which depends only on productivity in the agriculture sector:

$$N_{at} = \left(\frac{\overline{A}}{A_{at}} \right)^{\frac{1}{\alpha}} \tag{9}$$

Let $N_t = 1 - N_{at}$ be the total time that can be allocated between the manufacturing and service sectors. Then the problem is reduced to solving the following two-sector planner's problem:

$\max \sum \beta^t \left(\frac{\epsilon}{\epsilon-1} \right)$

$\log \left[\lambda \left(A_{mt} K_{mt}^{\theta} N_{mt}^{1-\theta} + (1-\delta) K_t - K_{t+1} \right)^{\frac{\epsilon-1}{\epsilon}} + (1-\lambda) A_{st}^{\frac{\epsilon-1}{\epsilon}} K_{st}^{\frac{\epsilon-1}{\epsilon}\theta} N_{st}^{\frac{\epsilon-1}{\epsilon}(1-\theta)} \right]$

$s.t$

$$K_{mt} + K_{st} = K_t \tag{10}$$

$$N_{mt} + N_{st} = N_t \tag{11}$$

The F.O.C for this problem are given by:

$$\lambda A_{mt} K_{mt}^{\theta-1} N_{mt}^{1-\theta} M_t^{-\frac{1}{\epsilon}} = (1-\lambda) A_{st}^{\frac{\epsilon-1}{\epsilon}} K_{st}^{\frac{\epsilon-1}{\epsilon}\theta-1} N_{st}^{\frac{\epsilon-1}{\epsilon}(1-\theta)} \tag{12}$$

$$\lambda A_{mt} K_{mt}^{\theta} N_{mt}^{-\theta} M_t^{-\frac{1}{\epsilon}} = (1-\lambda) A_{st}^{\frac{\epsilon-1}{\epsilon}} K_{st}^{\frac{\epsilon-1}{\epsilon}\theta} N_{st}^{\frac{\epsilon-1}{\epsilon}(-\theta)} \tag{13}$$

$$\frac{M_{t-1}^{-\frac{1}{\epsilon}}\varphi_{t-1}^{-1}}{M_t^{-\frac{1}{\epsilon}}\varphi_t^{-1}} = \beta\left[1-\delta+\theta A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta-1}\right] \tag{14}$$

where

$$\varphi_t = \lambda M_t^{\frac{\epsilon-1}{\epsilon}} + (1-\lambda)S_t^{\frac{\epsilon-1}{\epsilon}} \tag{15}$$

Equations (12) and (13) equate marginal products of capital and labor in manufacturing and services. Equation (14) states that the marginal rate of intertemporal substitution of the consumption good equals to the marginal rate of transformation of current consumption to future consumption.

Dividing equation (12) by (13) and combining with (10) and (11), yields:

$$\frac{K_{mt}}{N_{mt}} = \frac{K_{st}}{N_{st}} = \frac{K_t}{N_t} \tag{16}$$

i.e.; capital to labor ratios are equalized across sectors.

Using equation (16) in (12) leads to:

$$\frac{1-\lambda}{\lambda}\left(\frac{M_t}{S_t}\right)^{\frac{1}{\epsilon}} = \frac{A_{mt}}{A_{st}} \tag{17}$$

This equation gives the relative consumption of services and the manufactured good. Note that this ratio depends only on current period productivities. Let C_t be the non-agricultural aggregate expenditures. I show in the appendix that:

$$C_t = \frac{\varphi_t M_t^{\frac{1}{\epsilon}}}{\lambda} \tag{18}$$

where φ_t is as defined in equation (15).

Equations (14) and (18) then imply:

$$\frac{C_t}{\beta C_{t-1}} = 1-\delta+\theta A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta-1} \tag{19}$$

This equation is similar to the standard Euler equation for the one sector growth model if one notes that the manufacturing and service sectors can be aggregated to one sector with production function:

$$F(K_t, N_t) = A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta} N_t \tag{20}$$

Equations (9), (16), (17), (19) and the resource constraint equations (10) and (11) completely characterize the equilibrium allocations. I show in the appendix that one can reduce the problem of solving for the equilibrium allocations to a unique dynamic equation of capital.

$$\begin{aligned} K_{t+1} &= A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta} N_t + (1-\delta)K_t - \beta\left[1-\delta+\theta A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta-1}\right] \\ &\quad \left[A_{mt-1}\left(\frac{K_{t-1}}{N_{t-1}}\right)^{\theta} N_{t-1} + (1-\delta)K_{t-1} - K_t\right] \end{aligned} \tag{21}$$

Given the initial capital stock and transversality condition, we can solve for the path of aggregate capital stock for the economy using equation (21). Once capital is known, all other allocations can be easily derived. In particular, I show in the appendix that the quantity of labor used in the service sector is given by:

$$N_{st} = \frac{C_t}{A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta}\left[1+\left(\frac{\lambda}{1-\lambda}\right)^{\epsilon}\left(\frac{A_{st}}{A_{mt}}\right)^{1-\epsilon}\right]} \tag{22}$$

where C_t is given by:

$$C_t = A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta} N_t + (1-\delta)K_t - K_{t+1} \tag{23}$$

The strategy for computing the equilibrium allocations can be summarized as follows. Non-agricultural labor is computed using equation (9). From equation (21), I compute the path of aggregate capital in the economy. Equation (23) gives the sequence of the composite consumption good. Finally, from equation (22) I derive the hours in the service sector. The other series: sectoral capital, labor in manufacturing and sectoral outputs are then easily derived.

For the equilibrium prices, I normalize the price of the manufactured good to 1 in each period and let p_{at}, p_{st} be respectively the prices of the agricultural and service goods relative to the manufactured good. The wage rate and rental rate of capital are the marginal products of labor and capital of the manufacturing technology. Given wage equality between sectors, we have:

$$p_{st} = \frac{A_{mt}}{A_{st}} \tag{24}$$

This equation results from the equality of capital share in manufacturing and services which leads to the same capital to labor ratio across the two sectors. The relative price of the agricultural good is the wage rate divided by the marginal product of labor in agriculture[18]:

$$p_{at} = \frac{w_t}{\alpha A_{at} N_{at}^{\alpha-1}} \tag{25}$$

In the next sections, I will compute the transition dynamics of the model. In all cases, I don't assume that countries are on a balanced growth path. In the model's framework, a balanced growth path exists only when the agricultural sector disappear and manufacturing TFP grows at a constant rate. Moreover, it can be shown that if in addition, the elasticity of substitution between manufacturing and services is not unity, then there is structural transformation along the asymptotic balanced growth path[19].

3. Calibration to the US Economy

In this section, I calibrate the model to the US economy for the period 1950-2000. The sources and detail of the data series are explained in the appendix.

3.1. Parameter Values

The model is calibrated to match the U.S structural transformation and GDP per capita growth from 1950 to 2000. The model period is 1 year. The natural counterpart for labor input in the model is sectoral shares of hours worked, this will be used for the

[18]There is a long literature on dualism of the labor market in developing countries which the model abstract from.

[19]Ngai and Pissarides (2007) obtains a similar result in a more general model with 1 capital producing sector and $n-1$ symmetric consumption sectors. Asymptotically, their economy also converges to two sectors: the capital producing sector and the slowest consumption sector.

calibration[20]. The parameter values to determine are $\overline{A}, \beta, \delta, \epsilon, \lambda$ and the time series for A_{at}, A_{mt}, A_{st}. I assume constant TFP growth rates for manufacturing and services for the US.

Choosing values for the productivity levels $A_{i(i=a,m,s)}$ amounts to choosing units; therefore, I normalize those to 1 in 1950. I set the labor share in agriculture α to 0.7 to be consistent with the empirical findings of Hayami and Ruttan (1985) and Mundlank (2001). The capital share θ is set to 0.33 as estimated by Herrendorf and Valentinyi (2008).

Contrary to the standard calibration method for growth rates, discount factor and depreciation rate parameters, I don't assume that the US economy is on a balanced growth path[21]. Instead, I calibrate the parameters ($\gamma_m, \gamma_s, \beta,$ and δ) jointly to match four averages in the data from 1950 to 2000: average growth rate of GDP per capita, average growth rate of the price of services relative to manufacturing, average investment to output ratio and average capital to output ratio. Table 1 shows the targeted statistics from the model and the data.

The average GDP per capita growth rate is linked to the manufacturing TFP growth rate. Asymptotically, GDP growth depends only on manufacturing TFP growth. The average growth rate of the price of services relative to manufacturing will be used to find the service TFP growth rate. From equation (24), we have:

$$\log(p_{st}) = \log(A_{mt}) - \log(A_{st}) \tag{26}$$

Differentiating this equation with respect to time approximating, yield:

$$\Delta p_s = \gamma_m - \gamma_s \tag{27}$$

where Δp_{st} is the slope of the price of the service good relative to the manufactured good. From the Groningen 10-sector industry database, I calculated the relative price of services from 1950 to 2000[22]. On average, the price of services relative to manufacturing

[20]In the next session when applying the model to developing countries, I will use sectoral employment shares because data for sectoral hours is not available for all the countries considered in my sample.
[21]In 1950, the share of agriculture in total output was 7.9% and it decreased to 1.16% in 2000.
[22]See the data appendix for details .

increased by 0.88% per year. Then, $\gamma_s = \gamma_m - 0.0088$. The last two targeted statistics will help determine the discount factor β and depreciation rate δ.

The agricultural productivity growth rate parameter γ_{at} and the subsistence level $\overline{A}$ are determined using the agricultural share of hours worked. The growth rate of agricultural productivity is set so that the model matches the US agricultural shares of hours worked. I assume that the growth rate varies each decade starting in 1950[23]. The growth rate between two dates t_1 and t_2 is calculated as follows:

$$\gamma_{a_{t_1 t_2}} = \left(\frac{N_{at_1}}{N_{at_2}}\right)^{\frac{\alpha}{t_2 - t_1}} - 1 \tag{28}$$

where N_{at} is the agricultural share of hours at date t . The subsistence level is just the agricultural output in every period after the start of structural transformation. Because I normalized agricultural TFP to be 1 in 1950, it follows:

$$\overline{A} = N_{a1950}^{\alpha} \tag{29}$$

Lastly, I need to calibrate the initial capital k_0 and the parameters ϵ and λ. The parameter ϵ is the elasticity of substitution between manufacturing and services and λ is the weight of the manufactured good in the production of the composite good. The initial capital is chosen to match the share of hours in manufacturing in 1950. The calibrated value is 2.8. The parameters ϵ and λ determine the labor reallocation between the manufacturing and service sectors. For labor to be reallocated from the high productive sector (manufacturing) to the low productive sector (services), ϵ has to be between 0 and 1. In other words, $\frac{\epsilon-1}{\epsilon}$ has to be negative. I choose values of ϵ and λ to minimize the quadratic norm of the difference between the predicted and actual manufacturing shares of hours worked between 1950 and 2000. The corresponding values are: $\epsilon = 0.45$ and $\lambda = 0.01$. While there are no standard values for these two parameters, the estimates

[23] I did not assume constant productivity growth rate in agriculture for the entire period because labor allocated to the manufacturing and service sectors is very sensitive to labor in the agriculture sector. Moreover, such assumption would be hard to justify in light of the agricultural technology formulation and the path of agricultural share of hours worked.

by Duarte and Restuccia (2010) are respectively 0.4 and 0.04[24]. Table 2 summarizes the calibrated parameter values.

3.2. Structural Transformation of the US economy

This section provides some insights into how well the calibrated model fits the data. I use the calibrated model to compute the sectoral shares of hours of the US economy from 1950 to 2000 and compare them with the data series[25].

Figure 1 shows the structural transformation predicted by the model. It shows that the model does a good job at replicating the sectoral shares of hours worked. By construction, the model matches exactly the agricultural share of hours for the years used in the calibration. But the model also does a good job in the other years. Of greater interest is the fact that there is a close match between the model and the data in the other two sectors. In particular, the model traces very well the shares of hours in the manufacturing and service sectors until the early 1990s. However, starting from the mid 1990s, the data show a drop in manufacturing share of hours that is not well replicated by the model. This discrepancy is caused by two factors.

First, the model abstracts from increases in total hours worked. However, as Rogerson (2008) shows, there have been a substantial increase in total hours worked in the US starting from the mid 1980s and most of the increase occurred in the service sector. By abstracting from growth in total hours and using sectoral shares, the model does not capture the full increase in the share of services. I abstract from growth in total hours because such data is not available for the developing countries for which the model will be used to determine sectoral TFP paths in the next section.

The second issue is the assumption of constant growth rates for productivity in manufacturing and services. In fact, Brauer (2006) of the Congressional Budget Office reported that there was an acceleration of manufacturing productivity since 1979. In my model, this acceleration would lead to a decrease in the share of hours in manufacturing. Adding

[24] For Rogerson (2008), the corresponding values are 0.43 and 0.07 where in his model the value for λ corresponds to the weight of the goods producing sector, which includes agriculture.

[25] The data series has been filtered to focus on low frequency time series.

this improves the fit slightly but given that the model does fairly well, I avoid this to focus on the long run trend.

4. Sectoral TFP Paths for Developing Countries

In this section, I use the calibrated model to infer time paths of sectoral TFP for three developing countries at different level of development. Specifically, assuming all countries have the same preference parameters, I find series for sectoral TFP such that when fed into the model they replicate the structural transformation and path of GDP per capita of Cameroon, Brazil, and Korea for the period 1960-2000[26]. These countries are chosen to show that the model can be applied to different development experiences. Cameroon is a low income country which did not develop during the 40-year period. Brazil is a middle income country that grew fast in the beginning but slowed down in the 1980's. Korea started poor but grew so fast that it is now a developed country[27]

This exercise will allow me to compare paths of sectoral TFP and identify the least productive sectors as well as convergence or divergence to the US. The assumption of constant productivity growth rates in manufacturing and services for the entire period is not empirically plausible for all countries. Some of the countries show a clear change in the trend of income per capita, signaling a change in productivity[28].

The agricultural TFP level for country i at date t can be obtained as follows:

$$A^i_{at}(N^i_{at})^\alpha = \overline{A} = A^{us}_{at}(N^{us}_{at})^\alpha$$

Thus:

$$A^i_{at} = \left(\frac{N^{us}_{at}}{N^i_{at}}\right)^\alpha A^{us}_{at} \tag{30}$$

where A^{us}_{at} and N^{us}_{at} represent respectively the agricultural productivity and employment share for the US at time t.

[26]Bah and Brada (2009) uses this model to assess the productivity catch up in 10 transition countries of Eastern Europe.
[27]In 1960, Korea's GDP per capita relative to the US was similar to that of Cameroon.
[28]An important issue is to identify the source of these productivity changes. This is left for future work.

I calculate A^i_{at} every 10 years starting in 1960, and assume constant growth rates within each decade[29]. With the calculated growth rates, I can deduce the yearly agricultural TFPs. Korea had the fastest productivity growth in agriculture among the developing countries. On the other end, Cameroon had the worst productivity growth in agriculture during the whole period.

The other two productivity series and the initial capital stock are calibrated to match GDP per capita relative to the US in 1960, GDP per capita growth for the period 1960-2000 and the sectoral shares of employment in manufacturing and services. For the employment shares, I specifically target the initial shares and the reallocation to the service sector over the whole period. As mentioned earlier, some countries show clear changes in the trend of GDP per capita, signaling a change in TFP growth rates in manufacturing and services. For these countries, I divide the period 1960-2000 into sub-periods corresponding to the different trends in per capita GDP. For each sub-period, I match the average GDP per capita growth rate. To compute real GDP from the model, I use the sectoral US prices in 2000.

Before showing the relative sectoral TFP time series for all three countries, I will present a detailed analysis of the structural transformation process and economic growth for each country. I will also discuss the sectoral TFPs necessary for the aggregate outcomes and show how the model's outcomes compare to the data.

4.1. Growth and Structural Transformation for Cameroon

Cameroon had a poor economic performance between 1960 and 2000. Relative to the US, its GDP per capita declined from 7% in 1960 to 4% in 2000. While its average growth rate was 0.55% during the 40-year period, the path of GDP per capita shows two sub-periods with different growth trends. The first sub-period runs from 1960 to 1983 and is characterized by an average per capita GDP growth rate of 2.40%. But the growth rate was -2.14% between 1984 and 2000. Thus, with constant productivity growth in manufacturing and services, I cannot replicate the path of income per capita for Cameroon. Instead,

[29] The employment data is available at 10-year intervals.

the model requires positive productivity growth rates in manufacturing and services in the first sub-period, and negative rates in the second. The calibrated rates are 2% in manufacturing and 1.5% in services in the first sub-period. But they were respectively -1.8% and -4% in the second sub-period. These changes in growth rates are treated as unexpected. That is in the first period, the household expects that the manufacturing and service TFP growth rates will be constant for ever. After they change in 1983, the household will believe that the new rates will be constant for ever, etc ....

Panel (A) of figure 2 shows the path of GDP per capita relative to 1960. The model is able to replicate very closely the path of per capita GDP in the first sub-period but cannot match the full decline in the second. This is due to the fact that with moderate negative manufacturing TFP growth rate, the capital stock continues to grow albeit at a slower rate. The graph shows that the steep decline in the second sub-period washed away almost all the gain in income in the first sub-period. In fact, Cameroon's GDP per capita in 2000 was at its level in 1972.

Panel (B) shows the process of structural transformation that accompanied these 40 years of economic stagnation[30]. The first observation from the graph is that Cameroon reallocated a very small percentage of its workforce out of agriculture. Agricultural employment share declined from 78.5% to 66.2%. This implies that a major problem for Cameroon is agricultural productivity. As long as Cameroon doesn't improve its productivity in agriculture, it cannot move labor to the other two sectors with higher productivity growth. The sources of poor efficiency in the agricultural sector are diverse. They can be the result of poor soil fertility, lack of efficient farming techniques, lack of use of fertilizers and so on.

The second observation from the figure is that the employment share of the manufacturing sector increased less compared to the increase in services. Manufacturing employment share increased from 4.6% to 9.9% while the share of services increased from 16.9% to 23.9%. This means that most of the labor reallocation occurred between the agriculture and service sectors. In the model framework, the small increase in manufacturing

[30]The kinks that appear in the model's curves are due to the brusque changes in the sectoral TFP growth rates.

employment share is due to the low productivity of services relative to manufacturing. Thus, the second biggest problem for Cameroon is productivity in services.

4.2. Growth and Structural Transformation for Brazil

GDP per capita for Brazil increased nearly 2.5-fold between 1960 and 2000. But the time series shows two sub-periods with very different growth trends. From 1960 to 1980, Brazil experienced a rapid growth with an average growth rate of 4.2%. However, Brazil was almost stagnant between 1980 and 2000, growing on average by less than 0.8% per year[31]. Despite the fast growth in the first period, Brazil did not catch up to the US. Its GDP per capita was almost constant, around 20% of the US during the period.

Despite this mixed growth performance, Brazil experienced big changes in sectoral employment shares. Agricultural employment share decreased from 52% in 1960 to 24% in 2000. During the same period, manufacturing employment share increased first from 15% in 1960 to 22% in 1985, and then decreased to 19% by 2000. The service employment share increased by 24 percentage points for the whole period and was at 57% in 2000. This indicates that Brazil transitioned from the first to the second phase of its structural transformation process around 1985. One observation we can take from the changes of labor shares is that Brazil did not allocate a large percentage of its labor force to the manufacturing sector. One reason would be that the service sector was highly unproductive compared to the manufacturing sector especially in the second sub-period.

Calibrating the model to match income per capita growth and the structural transformation yields productivity growth rates at respectively 2.2% in manufacturing and 1.8% in services in the first sub-period. In the second sub-period, the growth rates were respectively 1.13% and -2.4%. Again, the changes in the growth rates are treated as unexpected and are assumed to be permanent.

With the inferred sectoral TFPs, the model is able to trace very closely the path of per capita GDP as shown in panel (A) of figure 3. Panel (B) shows the structural transformation of Brazil. The model is able to replicate the changes of employment

[31] It seems then appropriate to assume that there was a break in the rates of growth of the productivities in manufacturing and services.

shares in all three sectors. We can see that the employment share of services increased slightly more in the second sub-period than in the first. This is caused by the higher TFP growth differential between manufacturing and services in the second sub-period.

The analysis above shows that while the agriculture and manufacturing sectors were holding ground relative to the US, the service sector was not. In the second sub-period, there was a dramatic decline in service TFP. This was the driving force behind income stagnation for those 20 years. In fact, manufacturing TFP growth was high in both sub-periods.

4.3. Growth and Structural Transformation for Korea

Korea is a growth miracle. It was able to achieve and sustain high output growth for many years. GDP per capita increased nearly 13-fold and it was catching up to the US. It went from 9% of the US in 1960 to 50% in 2000. It also experienced substantial structural transformation in the period 1960-2000. The agricultural share of employment declined from 66% in 1960 to only 10% in 2000. The manufacturing employment share first increased from 9% in 1960 to 35% in 1991 and then declined to 28% in 2000. On the other hand, the service share of employment increased by 37 percentage points in the 40-year period. It increased from 24% to 62% of total employment. Korea fits very well the structural transformation process accompanying economic development as described by Kuznets[32].

The steady growth of GDP per capita from 1960 to 2000 is consistent with constant productivity growth rates both in the manufacturing and service sectors. The calibrated growth rates are 3.6% in manufacturing and 3.0% in services from 1960 to 2000. After 2000, I assume that these rates drop unexpectedly to the level of the US rates, implying that the catch up of Korea stops at this time. Figure 4 shows the GDP per capita growth and structural transformation of Korea. As can be seen in panel (A), the model replicates very well the path of GDP per capita relative to 1960. We can also see in panel (B), the model's labor reallocation between manufacturing and services matches the overall trend

[32]See Bah (2009) for a discussion of this topic

in the data but does not fit closely the time paths of sectoral employment shares[33].

These two figures show that the calibrated sectoral TFP time series are consistent with the paths of GDP per capita and sectoral employment shares for Korea. In addition, from the model's framework, we see that the underlying reason for Korea's fast income growth was the sustained increase in productivity for all three sectors. This is a key difference with Brazil which improved productivity in all three sectors between 1960 and 1980, but experienced a marked slowdown afterward.

4.4. Comparing Sectoral TFP Paths

In this subsection, I summarize the paths of sectoral TFP relative to the US for the three countries. This will highlight the least productive sectors in each country. Figure 5 plots the relative productivities in the three sectors. Panel (A) shows the relative TFP in agriculture. Between 1960 and 1970, the US had a high TFP growth in agriculture, therefore all other countries had downward slopping relative TFPs. However since 1970, US agricultural TFP growth was not so high and most of the countries had increasing relative TFPs. The highest productivity growth was for Korea, where relative TFP more than doubled increasing from 16% in 1970 to 40% in 2000. Brazil's relative TFP increased somewhat after 1970 but it was only around 21% as of 2000. As I mentioned earlier, Cameroon is very unproductive in agriculture. Its relative productivity declined from 12% to 10% of the US in the period 1970-2000.

As can be seen in panel (B), the relative TFPs for manufacturing are higher than those of the agriculture sector. Korea started with lower relative manufacturing TFP than Brazil but it ended up being the highest by 2000. It increased from 36% of the US in 1960 to 85% in 2000. Brazil had high growth in the first sub-period, which slowed down in the second. Despite of this, relative manufacturing TFP increased from 50% to 57% in the period 1960-2000. Cameroon had a declining relative manufacturing TFP for both subperiods with a much bigger decline in the second subperiod. Its manufacturing TFP declined from 35% of the US in 1960 to 22% in 2000.

[33] A plausible reason is that the assumption of closed economy may be too strong for Korea.

Panel (C) shows the time path of relative TFP for services . Korea experienced a sustained growth and more than doubled its relative service TFP, increasing from 31% in 1960 to 82% in 2000. On the other end, Cameroon had a big decline in the whole period, from 26% in 1960 to 14% in 2000. For Brazil, after a catch-up in the first sub-period, it experienced a big decline in the second. Service TFP increased from 45% of the US in 1960 to 53% in 1980 but declined to 30% in 2000.

Comparing the relative sectoral TFPs, all countries are the least productive in agriculture, followed by services and then manufacturing. One way to show this is to divide relative agricultural TFP by relative service TFP and relative service TFP by relative manufacturing TFP. Due to a big decline of productivity in services, Cameroon's relative agricultural TFP increased from 68% of relative service TFP in 1960 to 74% in 2000. A similar phenomenon occurred in Brazil where relative agricultural TFP increased from 52% of relative service TFP in 1960 to 72% in 2000. For Korea it was the opposite. Relative TFP increased in both sectors but faster in services. Relative agricultural TFP declined from 64% of relative service TFP in 1960 to 48% in 2000. The comparison between relative service TFP and manufacturing shows similar trends. For Cameroon and Brazil, there were bigger declines of relative productivity for services than manufacturing. Korea was catching up to the US in both sectors but with a slightly higher rate in services. Cameroon's relative service TFP decreased from 74% of manufacturing TFP in 1960 to 63% in 2000. The decline was from 90% in 1960 to 52% for Brazil. Korea's relative service TFP increased from 86% of relative manufacturing TFP in 1960 to 97% in 2000.

5. Discussion of the Findings

Before discussing my findings on relative sectoral TFP, I use my calculated aggregate capital from the model to conduct a simple growth accounting for Korea and show that the estimates are in line with studies in the growth accounting literature. Table 3 shows the growth rate and contribution to output growth of capital, labor and TFP. Output grew on average at the annual rate of 6.6%, capital by 9.47% and TFP by 1.83%. The contribution of capital to output growth was 46% while TFP contributed at 28%. In the growth accounting literature, there is a range of estimates for the growth rate of aggregate productivity and its contribution to output growth. The average growth rate of TFP at different time intervals varies between 1.3% to 4.1% (see table XI in Young (1995)). However, the consensus seems that growth of the inputs, especially capital, contributed more to output growth. Young (1995) estimates that productivity grew on average 1.7 % and contributed to 17% of output growth while capital contributed to 40% for the period 1966-1990. With a higher capital share, Bosworth and Collins (1996) estimates that between 1960 and 1994, capital contributed to 58% in output per worker growth and TFP contributed to 26%. My estimates, which don't include the contribution of human capital, are well within the range found in the literature.

As noted earlier, the finding that agriculture is the least productive sector in developing countries is not new, therefore I will not discuss it here[34]. The interesting finding is that relative to the US, the developing countries considered here are less productive in services compared to manufacturing. This finding is consistent with studies that use micro data and those that examine labor productivity. Bailey and Solow (2001) and Baily et al. (2005) used collected data at the firm level by the McKinsey Global Institute to compare labor productivity across sectors for few developed and developing countries[35]. They find that relative to the US, other countries are less productive in services than manufacturing. One notable example is Japan, which is more productive than the US in many manufacturing sub-sectors (e.g. Auto, Steel, Consumer Electronics, Metalworking) but is far behind in services. This relative productivity ranking holds true for Brazil and Korea although Korea is very productive in some services like Telecom and Airlines.

Using a similar three-sector model without capital accumulation, Duarte and Restuccia (2010) finds that relative to the US, other countries are less productive in agriculture, followed by services and then industry. Their paper uses data on labor productivity from

[34]See Restuccia et al. (2008); Gollin et al. (2004) for a detailed discussion of the topic.

[35]They also have sectoral TFPs for few sectors and few countries. They find that, in general, the ranking of sectoral TFP follows that of labor productivity.

the Groningen 10-sector database for 29 developed and developing countries and uses the model to back out PPP-conversion factors across countries. Herrendorf and Valentinyi (2007) also infers sectoral TFP across countries from a general equilibrium model. Using relative prices obtained from the expenditure data of the 1996 benchmark studies of the Penn World Table (PWT), they finds that relative TFP differences between the US and developing countries are small in services compared to sectors producing consumption goods, construction and equipment goods.

While this paper provides an innovative methodology to circumvent the data limitation for sectoral productivity analysis in developing countries, it makes few assumptions. The first is the assumption of closed economy. Following the literature on structural transformation, this assumption is made to simplify the analysis. Moreover, the assumption seems reasonable given these kind of models with a single manufacturing good, a non tradable service sector and an agriculture sector producing only food which only a very few developing countries trade[36]. As noted earlier this assumption may be strong for countries like Korea with big manufacturing exports. However allowing for trade in manufacturing will strengthen my results for such countries. First, there is a strong evidence that only the best productive firms engage in exports. Second, the exports market provides additional demand for the manufacturing sector which requires slow reallocation of resources to services despite a sizeable productivity growth differential[37].

Another assumption concerns the agricultural technology which uses only labor and land with no capital, no intermediate inputs and no distortions. Indeed there are a number of papers that indicate these are important to explain the low productivity in agriculture. While extending the model to include any of these will have a quantitative effect on agricultural TFP, it will not alter the finding that agriculture is the least productive sector which is very robust finding of the development literature. Also it will not affect the sectoral TFPs for the other two sectors because what is critical for their determination is to have the correct level of non-agricultural labor; capital is endogenously

[36] Gollin et al. (2007) used data from Food and Agriculture Organization (FAO) and concluded that only a few developing countries engage in food trade.

[37] This explains why my model with the closed economy assumption predicts a smaller manufacturing employment share than what is observed in the data for Korea.

determined. The model also makes the assumption of no dual labor market and wages are equalized across sectors. If the duality of the labor market is between agriculture and non-agriculture, then the above argument applies. However, there is some evidence that wages in some service sub-sectors (like retail) are lower than those in manufacturing. This model is too aggregated to deal with such an issue. Another interesting departure is to have different kind of labor (skilled vs unskilled). Future work will address these issues.

6. Conclusion

This paper shows that we can use time series data on sectoral employment shares and GDP per capita to infer time series of sectoral TFP. The proposed approach develops a three-sector model where non-homothetic preferences and differences in sectoral productivity drive labor reallocation across sectors. In this framework, labor moves to the slowest growing sectors. The model is calibrated to the US and is shown to replicate the structural transformation process of the US economy for the period 1950-2000. Applying the calibrated model to developing countries leads to the interesting finding that relative to the US, developing countries are the least productive in services compared to manufacturing. This finding results from the fact that the countries allocate a greater percentage of their labor force to the service sector rather than manufacturing.

A key innovation of this paper is the use of panel data on sectoral employment and GDP per capita, which allows us to compute time series for sectoral TFPs. This is important because many developing countries experience large changes in GDP growth over time which suggests that their sectoral TFPs undergo large changes over time as well. With long time series, we can find not only the least productive sectors in developing countries, but also the sectoral sources of big changes in GDP per capita for a given country.

While sectoral TFP growth differentials and non-homotheticity have been the key driving forces of labor reallocation in this model, such reallocation can also be the result of interaction between distortions in the labor market and sectoral productivity. We also need to understand how and why policies and institutions affect sectors differently. These questions are left for future research.

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A. Appendix A: Data Sources

The calibration of the model to the US economy requires data for GDP per capita, sectoral shares of hours worked, price of services relative to manufacturing, investment to output and capital to output. The data for GDP per capita, expressed in 1990 international Geary-Khamis dollars, is from the "Historical Statistics for the World Economy: 1-2006 AD" by Maddison (2009). The shares of sectoral hours worked and the price of services relative to manufacturing are from the Groningen 10-sector database. In the database, the economy is disaggregated into 10 sectors. The value-added of each sector is given in both constant and current prices. I aggregated those sectors into the 3 sectors used throughout this paper. Manufacturing includes mining, manufacturing, utilities and construction. I calculate the price of a sector by dividing its value added in current prices by the value added in constant prices. The price of services relative to manufacturing is deduced form there. This database also contains the sectoral hours worked for the US between 1950 and 1997. For the period, 1998-2000, I use the 60-sector industry database. I obtained investment series from the NIPA tables and used the perpetual inventory method to calculate capital stocks.

For the application of the model to the developing countries, I need data on sectoral employment and GDP per capita. The employment shares data is obtained from the World Bank tables (1983) for the years 1960, 1965 and 1970 and World Development Indicators online database from 1971. The per capita GDP is from Maddison.

The GDP per capita and sectoral employment shares data series for the US and developing countries have been filtered using the H-P filter to focus on low frequency trends.

B. Appendix B: Figures, Proofs and Tables

B.1. Proofs

Proof 1: Deriving equation for the non-agricultural aggregate expenditure C_t

$$C_t = M_t + p_{st} S_t \tag{31}$$

Using equation (24) yields:

$$C_t = M_t + \frac{A_{mt}}{A_{st}} S_t \tag{32}$$

We also know that $\Phi_t(M_t, S_t)$ is homogenous of degree 1, therefore:

$$\Phi_t(M_t, S_t) = \Phi_1 M_t + \Phi_2 S_t \tag{33}$$

$$\Phi_1 = \lambda M_t^{-\frac{1}{\epsilon}} \varphi_t^{\frac{1}{\epsilon}} \tag{34}$$

$$\Phi_2 = (1-\lambda) S_t^{-\frac{1}{\epsilon}} \varphi_t^{\frac{1}{\epsilon}} \tag{35}$$

But from equation (17), we have:

$$\frac{1-\lambda}{\lambda}\left(\frac{M_t}{S_t}\right)^{\frac{1}{\epsilon}} = \frac{A_{mt}}{A_{st}} \tag{36}$$

Then:

$$\Phi_2 = \frac{A_{mt}}{A_{st}} \Phi_1 \tag{37}$$

This implies:

$$\Phi_t = \Phi_1 M_1 + \frac{A_{mt}}{A_{st}} \Phi_1 S_t = \Phi_1 \left(M_t + \frac{A_{mt}}{A_{st}} S_t\right) = \Phi_1 C_t \tag{38}$$

Replacing Φ_1 by its expression, yields:

$$C_t = \frac{\varphi_t M_t^{\frac{1}{\epsilon}}}{\lambda} \tag{39}$$

where φ_t is as defined in 15

Proof 2: Deriving the dynamic equation for capital

From equations (32) and (18):

$$C_t = M_t + A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta} N_{st} \tag{40}$$

Then:

$$C_t = A_{mt}\left(\frac{K_{mt}}{N_{mt}}\right)^{\theta} N_{mt} + (1-\delta)K_t - K_{t+1} + A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta} N_{st} \tag{41}$$

Since $\frac{K_{mt}}{N_{mt}} = \frac{K_t}{N_t}$, this reduces to:

$$C_t = A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta} N_t + (1-\delta)K_t - K_{t+1} \tag{42}$$

This implies:

$$K_{t+1} = A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta} N_t + (1-\delta)K_t - C_t \tag{43}$$

Combining equations (19) and (43), we get the following dynamic equation for the aggregate capital stock:

$$\begin{aligned} K_{t+1} \quad = \quad & A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta} N_t + (1-\delta)K_t - \beta\left[1-\delta+\theta A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta-1}\right] \\ & \left[A_{mt-1}\left(\frac{K_{t-1}}{N_{t-1}}\right)^{\theta} N_{t-1} + (1-\delta)K_{t-1} - K_t\right] \end{aligned} \tag{44}$$

Proof 3: Deriving labor used in services

From equations (17) and (16), we have:

$$M_t = A_{mt}\left(\frac{\lambda}{1-\lambda}\right)^{\epsilon}\left(\frac{A_{st}}{A_{mt}}\right)^{1-\epsilon}\left(\frac{K_t}{N_t}\right)^{\theta} N_{st} \tag{45}$$

Combining equations (40) and (45), we get:

$$C_t = M_t + A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta} N_{st} = A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta}\left[1+\left(\frac{\lambda}{1-\lambda}\right)^{\epsilon}\left(\frac{A_{st}}{A_{mt}}\right)^{1-\epsilon}\right] N_{st} \tag{46}$$

From equation (46) we can get the quantity of labor used in the service sector.

$$N_{st} = \frac{C_t}{A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta}\left[1+\left(\frac{\lambda}{1-\lambda}\right)^{\epsilon}\left(\frac{A_{st}}{A_{mt}}\right)^{1-\epsilon}\right]} \tag{47}$$

B.2. Figures and Tables

Table 1: Statistics in the Data and the Model

Statistics, average 1950-2000	Data (%)	Model (%)
Per Capita GDP Growth Rate	2.10	2.10
Capital to Output Ratio	2.40	2.40
Investment to Output Share	20.30	20.70
Growth Rate of Price of Services / Manufacturing	0.88	0.88

Table 2: Calibrated Parameters

A_a	A_m	A_s	$\overline{A}$	α	β	δ	ϵ	λ	θ	γ_m	γ_s
1	1	1	0.24	0.7	0.97	0.04	0.45	0.01	0.33	0.014	0.0052

Table 3: Growth Accounting for Korea

	Annual growth rate	Contribution to output
Output	0.0667	1.00
Capital	0.0947	0.47
Labor	0.0251	0.25
TFP	0.0183	0.28

NOTE: The output is for the non-agricultural sectors.

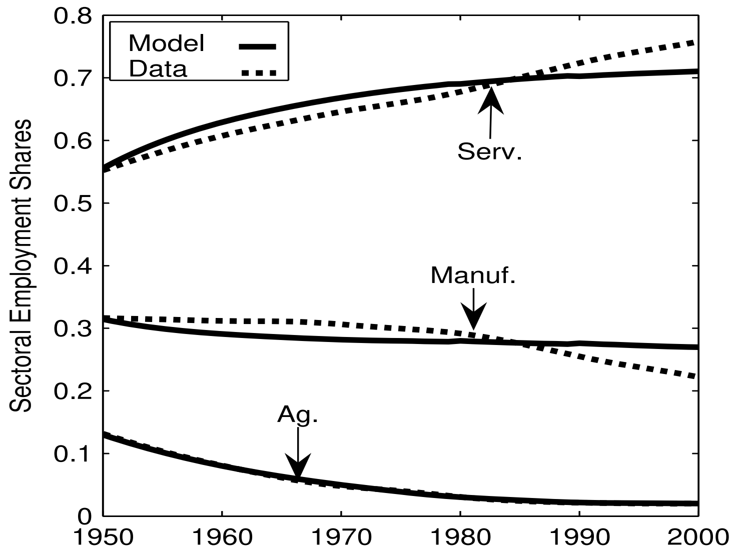
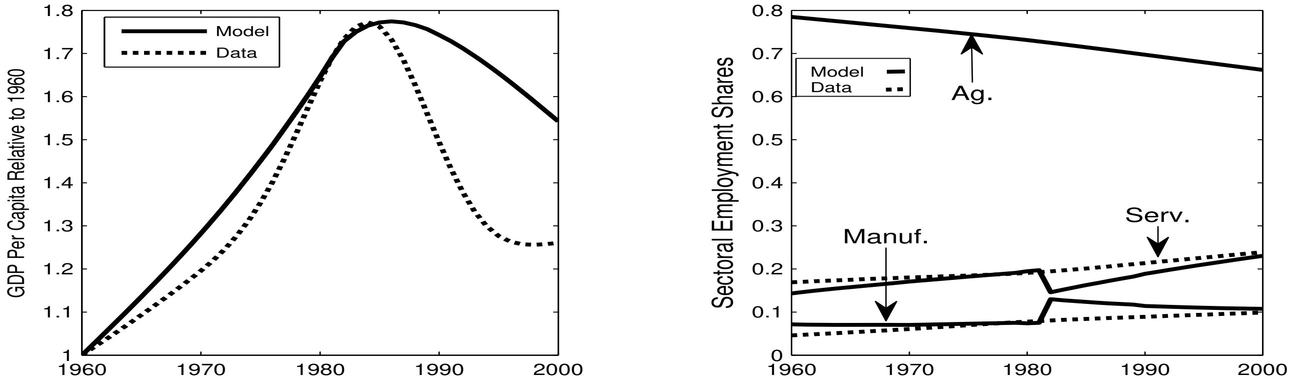


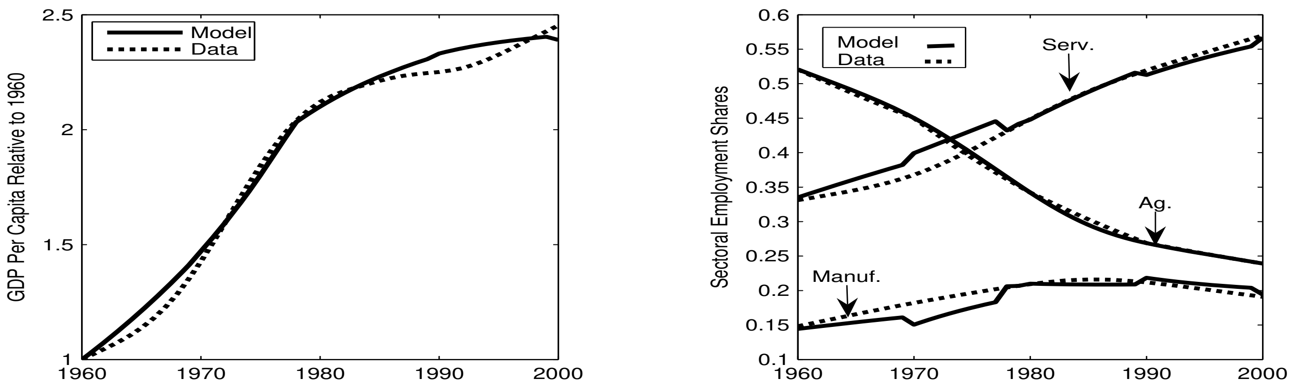
Figure 1: Structural Transformation for the US, 1950-2000



(A) Per Capita GDP

(B) Structural Transformation

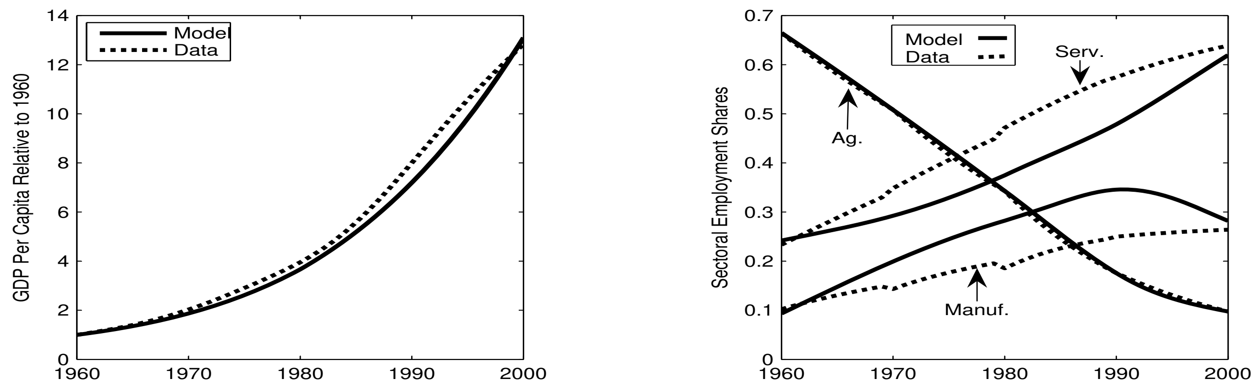
Figure 2: Cameroon



(A) Per Capita GDP

(B) Structural Transformation

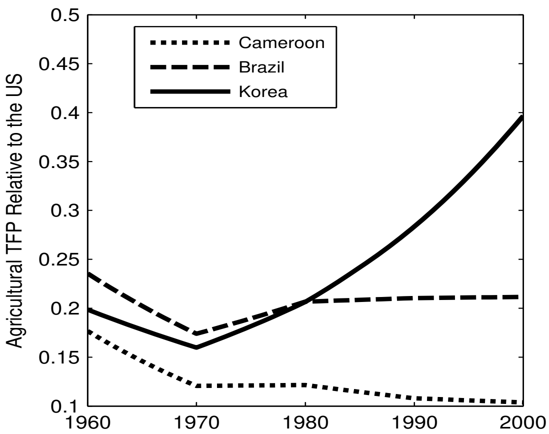
Figure 3: Brazil



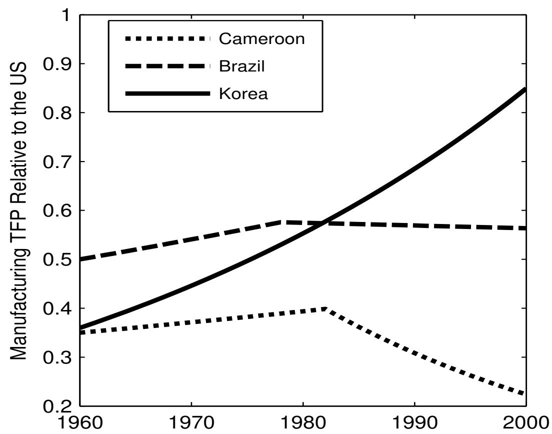
(A) Per Capita GDP

(B) Structural Transformation

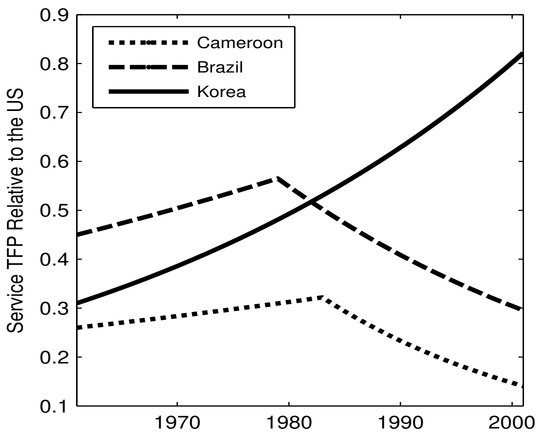
Figure 4: Korea



(A) Agriculture



(B) Manufacturing



(C) Services

Figure 5: Sectoral TFP Paths