Sectoral Productivity in Developing Countries

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Sectoral Productivity in Developing Countries*

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This paper seeks to understand which sectors account for the total factor productivity (TFP) gap between rich and poor countries. I use a three-sector model of structural transformation to estimate sectoral TFP paths consistent with the reallocation of labor between sectors and GDP per capita growth of a set of developing countries over a 45-year period. I find that relative to the US, developing countries are the least productive in agriculture, followed by services, and then industry. The findings confirm rankings of sectoral labor productivity and are consistent with TFP estimates from EU KLEMS for developed countries. The decomposition of labor productivity growth in capital intensity and TFP contributions shows large variations across countries and sectors. However, the paper consistently finds that countries or sectors with the worst growth performances suffered mostly from low or negative TFP growth.

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 2005 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.[2] 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[3].

This paper uses differences in structural transformation processes across countries to find paths of sectoral TFPs (Bah, 2011; McMillan and Rodrik, 2012). The paper extends Duarte and Restuccia (2010) to decompose labor productivity into capital productivity and TFP. Growth accounting exercises conducted for the growth miracle economies of East Asia have shown that aggregate capital accumulation played a dominant factor in their success. The decomposition of labor productivity can help understand the roles played by sectoral capital accumulation and total factor productivity growth in driving labor reallocation across sectors and contributions to sectoral performance. The model extends the neoclassical growth model to include three sectors (agriculture, industry and services) and it is used to infer time series of sectoral TFP consistent with GDP per capita

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

[2]For developed countries, the EU KLEMS database constructed comparable TFP estimates for up 72 industries. This data has been used by Bah (2013) to analyze the European income catch-up to the US.

[3]See Hsieh and Klenow (2007) and Herrendorf and Valentinyi (2012).

growth and labor reallocation over a 45-year period. This is important because developing countries experience large changes in GDP per capita and productivity along their development processes. Therefore, computing time series of sectoral TFPs along development processes will provide important insights. Following Rogerson (2008) and Duarte and Restuccia (2010), 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[4]. Second, a TFP growth differential and the elasticity of substitution between industry and services drive the reallocation of labor between those two sectors[5].

I calibrate the model to match the structural transformation and per capita GDP growth in the US over the period 1950-2005. 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 nine developing countries from Asia and Latin America: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Korea, Mexico and Venezuela[6].

In this exercise, I assume that preferences are similar across countries but allow all sectoral TFPs to vary. I show that, with 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 industry and services determines the relative TFPs of those two sectors. Finally, aggregate GDP per capita determines the levels of TFP in industry 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 industry. While all countries were catching up to the US in agriculture, almost all were losing ground in industry and

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

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

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

services. The exception were Chile and Korea. After an initial low growth in the period 1960-1983, Chile experienced fast TFP growth in both industry and services. Korea, on the other hand, grew faster than the US in all three sectors since 1960.

My findings on relative sectoral productivity confirm the findings of Duarte and Restuccia (2010) and are consistent with the available evidence from micro and producer price 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 the productivity of agriculture and non-agriculture[7]. There is also a large literature that estimates agricultural production functions across countries and try to find the determinants of low productivity for developing countries[8].

Between industry 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 industry. 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. In contrast, Herrendorf and Valentinyi (2012) 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 also related to 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 economic growth. Hsieh and Klenow (2007) and Herrendorf and Valentinyi (2012) also use general equilibrium models to infer sectoral TFPs but instead use cross-section price data from the PWT. Hsieh and Klenow (2007) focus on sectors producing consumption and investment goods while Herrendorf and Valentinyi (2012) include services, consumption

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

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

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

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 industry[10] and services. This is the first phase of structural transformation. In the second phase, labor moves from agriculture and industry into services. This process of structural transformation has been followed by current developed countries but as Bah (2011) and McMillan and Rodrik (2012) document, 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 emphasizes differences in sectoral productivity growth as the main feature explaining differences in structural transformation processes. The model is calibrated to match the growth and structural transformation of the US economy for the period 1950-2005. In the next section, the calibrated model is used to infer sectoral TFPs for a selection of developing countries.

2.1. Model

The economy has three sectors each producing one good: agriculture, industry, and services. A key for the model is to replicate the labor reallocation across different sectors of the economy. This has been traditionally achieved by incorporating an income effect or

[10] In this paper, industry and manufacturing are used interchangeably. The exact definition of the sector is in the data appendix.

a price differential effect. The income effect, derived from non-homothetic preferences, leads to a decline in the share of agricultural consumption as income increases and an increase in the consumption share of services (Echevarria, 1997; Laitner, 2000; Caselli and Coleman II, 2001; Kongsamut et al., 2001; Gollin et al., 2002). The second feature uses relative price differentials (Baumol, 1967; Ngai and Pissarides, 2007) resulting from the growth differential in sectoral productivities to achieve the labor reallocations observed in the data. Starting with Rogerson (2008), recent works combine the two features in the same framework with the income effect driving the reallocation of labor out of agriculture and technological growth differentials driving the reallocation between industry and services. Herrendorf et al. (2009, 2013) discuss in detail the mechanisms of structural transformation and the specification adopted here with their findings. The model assumes a closed economy and the implications of trade will be discussed later.

2.1.1. Preferences

There is an infinitely lived representative household with constant size. 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 industry and service sectors.

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

$V(A_t)$ is non-homothetic and is given by[11]:

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

[11] This formulation, following Gollin et al. (2002), allows for the easy separation of the agriculture sector and the non-agriculture sectors in the solution methodology.

where $\overline{A}$ is the subsistence level below which the household cannot survive.

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

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

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: 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 affected. However, it is unlikely that this will overturn the finding that agriculture is relatively the least productive sector in developing countries which is a 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[12]. Another source of variation

[12]Restuccia et al. (2008) finds that the lack of use of intermediate inputs and distortions in the labor

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.

Industry 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[13]. Output from industry is used for consumption (M_t) in the composite good and investment (X_t). The 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 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, the 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.

market explain a big part of the large disparity in agricultural productivity between rich and poor countries

[13] Their estimates are 0.33 for industry and 0.34 for services. This assumption will lead industry 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.

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[14]. Note that there are no distortions in the economy, therefore the equilibrium allocations can be obtained by solving a social planner's problem[15]. 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

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

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

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

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

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

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

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

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 that sector:

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

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

[15] A large body of the development literature argues that distortions in both factors and output markets are a fundamental obstacle to development. This paper abstracts from that debate.

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:

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

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

$s.t$

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

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

It is easy to show that capital to labor ratios are equalized across sectors:

$$\frac{K_{mt}}{N_{mt}} = \frac{K_{st}}{N_{st}} = \frac{K_t}{N_t} \tag{12}$$

The dynamic equation for capital is given:

$$\begin{aligned} K_{t+1} &= A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta} N_t + (1-\delta)K_t - \beta\left[1-\delta+\theta A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta-1}\right] \\ &\left[A_{mt-1}\left(\frac{K_{t-1}}{N_{t-1}}\right)^{\theta} N_{t-1} + (1-\delta)K_{t-1} - K_t\right] \end{aligned} \tag{13}$$

Given the initial capital stock and transversality condition, we can solve for the path of aggregate capital stock for the economy using equation (13). Once capital is known, all other allocations can be easily derived. In particular, the quantity of labor used in the service sector is given by:

$$N_{st} = \frac{C_t}{A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta}\left[1 + \left(\frac{\lambda}{1-\lambda}\right)^{\epsilon}\left(\frac{A_{st}}{A_{mt}}\right)^{1-\epsilon}\right]} \tag{14}$$

where C_t is given by:

$$C_t = A_{mt}\left(\frac{K_t}{N_t}\right)^{\theta} N_t + (1-\delta)K_t - K_{t+1} \tag{15}$$

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:

$$p_{st} = \frac{A_{mt}}{A_{st}} \tag{16}$$

This equation results from the equality of capital share in industry 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[16]:

$$p_{at} = \frac{w_t}{\alpha A_{at} N_{at}^{\alpha-1}} \tag{17}$$

In the next sections, I compute the transition dynamics of the model. In doing so, I do not assume that countries are on a balanced growth path. In the model's framework, a balanced growth path exists only when the agricultural sector disappears and manufacturing TFP grows at a constant rate. Moreover, it can be shown that if in addition, the elasticity of substitution between industry and services is not unity, then there is structural transformation along the asymptotic balanced growth path[17].

3. Calibration to the US Economy

In this section, I calibrate the model to the US economy for the period 1950-2005. 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 2005. The model period is 1 year. The natural counterpart for

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

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

labor input in the model is sectoral shares of hours worked. This will be used for the calibration[18]. 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 industry 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 do not assume that the US economy is on a balanced growth path[19]. Instead, I calibrate the parameters ($\gamma_m, \gamma_s, \beta,$ and δ) jointly to match four averages in the data from 1950 to 2005: average growth rate of GDP per capita, average growth rate of the price of services relative to industry, 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 industry will be used to find the service TFP growth rate. From equation (16), we have:

$$\log(p_{st}) = \log(A_{mt}) - \log(A_{st}) \tag{18}$$

Differentiating this equation with respect to time and approximating yields:

$$\Delta p_s = \gamma_m - \gamma_s \tag{19}$$

where Δp_{st} is the slope of the price of the service good relative to the manufactured good. From the Groningen Growth and Development Centre 10-sector industry database, I calculated the relative price of services from 1950 to 2005[20]. On average, the price of

[18]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.
[19]In 1950, the share of agriculture in total output was 7.9% and it decreased to 1.16% in 2005.
[20]See the data appendix for details.

services relative to industry increased by 0.88% per year. Then, $\gamma_s = \gamma_m - 0.0088$. The derived average growth rates are 1.4% for industry and 0.52% for services. 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[21]. The growth rate between two dates t_1 and t_2 is calculated as follows:

$$\gamma_{a_{t_1 t_2}} = \left(\frac{N_{at_1}}{N_{at_2}}\right)^{\frac{\alpha}{t_2 - t_1}} - 1 \tag{20}$$

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:

$$\overline{A} = N_{a1950}^{\alpha} \tag{21}$$

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 industry 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 industry in 1950. The calibrated value is 2.8. The parameters ϵ and λ determine the labor reallocation between the industry and service sectors. For labor to be reallocated from the high productive sector (industry) 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 2005. The corresponding values are: $\epsilon = 0.45$ and $\lambda = 0.01$. While there are no standard values for these two parameters, the estimates by Duarte and Restuccia (2010)

[21] I did not assume constant productivity growth rate in agriculture for the entire period because labor allocated to industry and services is sensitive to labor in agriculture. Moreover, such assumption is hard to justify in light of the agricultural technology formulation and the path of the agricultural share of hours worked.

are respectively 0.4 and 0.04[22]. 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 for the US. I use the calibrated model to compute the sectoral shares of hours of the US economy from 1950 to 2005 and compare them with the data series[23].

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 close match between the model and the data in the other two sectors. In particular, the model traces well the shares of hours in the industry and service sectors until the early 1990s. However, starting from the mid 1990s, the data show a drop in the industry share of hours that is not well replicated by the model. This discrepancy has been observed in other studies (Bah, 2013; Buera and Kaboski, 2009; Ungor, 2011). All closed economy models without distortions are unable to match the faster reallocation of labor from industry into services starting from the mid-1980s. Bah (2013) has shown that adding a time-varying labor distortion in the services sector allows a similar model to match the paths of sectoral shares of employment. Moreover, allowing for trade has the potential of contributing to the faster de-industrialization of the US but the magnitude of this contribution is still not clear.

The model has also predictions about the labor productivity that can be decomposed into capital intensity and TFP as follows:

$$Y_t = A_t K_t^{\alpha} N_t^{1-\alpha} \Rightarrow y_t = \frac{Y_t}{N_t} = A_t (K_t/N_t)^{\alpha}$$

[22]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.

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

By taking logs, differentiating and approximating, we get:

$$gy_n = g_A + g_k \tag{22}$$

where gy_n is the average growth rate of labor productivity, g_A is the average growth rate of TFP and g_k is the average growth rate of $(K_t/N_t)^\alpha$, which capital intensity. This decomposition is valid for the aggregate economy and the non-agricultural sectors. Notice also that the capital intensity for industry and services is the same as the aggregate capital intensity because there are no distortions and capital shares are the same (see equation (12)).

From the data, value added per hour grew on average by 1.86% per year for the period of 1950-2005. The corresponding prediction of the model is 2.0% per year. About half of the growth rate comes from capital intensity and the other half from aggregate TFP. The predicted growth rates for the sectors are 3.53%, 2.46% and 1.57%. The corresponding rates in the data are 3.36% for agriculture, 2.35% for industry and 1.5% for services. Therefore, the model's predictions are very close the actual rates. The decomposition for industry shows that TFP contributed more than capital intensity accounting for 57% of the growth of labor labor productivity. For services, it is the opposite with capital intensity contributing to 66% of the growth in labor productivity (see table 3).

4. Sectoral TFP Paths for Developing Countries

In this section, I use the calibrated model to infer time paths of sectoral TFP for nine developing countries. 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 for Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Korea, Mexico and Venezuela for the period 1960-2005[24]. These countries are the developing countries in the larger data set of Duarte and Restuc-

[24]Bah and Brada (2009) uses this model to assess the productivity catch up in 10 transition countries of Eastern Europe.

cia (2010), which includes developing countries also. My choice of countries is driven for comparability and data limitation reasons. The exercise will allow me to identify the least productive sectors compare paths of sectoral TFPs as well as to discuss convergence or divergence vis-a-vis the US.

The assumption of constant productivity growth rates in industry and services for the entire period is no longer 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.

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:

$$A^i_{at} = \left(\frac{N^{us}_{at}}{N^i_{at}}\right)^\alpha A^{us}_{at} \tag{23}$$

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

I calculate A^i_{at} every 10 years starting in 1960, and assume constant growth rates within each decade. With the calculated growth rates, I can deduce the yearly agricultural TFPs.

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 1960-2005 and the sectoral shares of employment in industry 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 industry and services. For these countries, I divide the period 1960-2005 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 prices in 2005 for the US economy. Before showing the relative sectoral TFP time series for all countries, I discuss how well the model fit the data in a number of dimensions: sectoral employment shares, GDP per capita relative to the US in 1960, average growth rates of GDP per capita for 1960-2005 and aggregate TFP relative to the US.

To compute aggregate TFPs for the period 1960-2005, I used the perpetual inventory method and data on investment shares from the Penn World Tables (PWT) to estimate aggregate capital of each country. The labor input is the total labor force from the World Development Indicators database (WDI).

Figure 2 shows the changes in employment shares in the model and the data for each sector. The change in employment shares is the difference between the initial and final shares. The first panel shows that the model matches exactly the changes in the data for agriculture. This is not surprising given the calibration methodology for agriculture. However, we also see in the next two panels that the model does a good job in matching the data for most countries. As in Duarte and Restuccia (2010), the model implies a smaller reallocation of labor out of industry than what is observed in the data. Consequently the model overestimates the share of labor reallocated into services. This indicates that for some countries abstracting from labor distortions in those two sectors is quantitatively significant. The last panel shows that the changes in aggregate TFP relative to the US inferred from the model are also close to the estimates from the data.

In figure 3, I plot the levels in 2005 of sectoral employment shares and relative aggregate TFP. As in the previous figure, there is a perfect match for agriculture and relatively good match in the two other sectors and for aggregate TFP. Again the model overestimates the share of industry and underestimate the one for services. In figure 4, I show for each country the initial GDP per capita relative to the US and the average growth rate of GDP per capita for the period 1960-2005. The model matches the data perfectly for the growth rates and very closely for most countries for relative GDP. The biggest gap between the model and the data for initial relative GDP per capita is for countries that started with high GDP per capita but grew slowly during the period (e.g. Argentina and Venezuela).

I assess the predictions of the model for labor productivity growth in figure 5. Overall, the model matches the average growth rates in the data. However, the model fail to match the data for extremely high or low growth rates such as the high growth of agriculture in Chile and the negative growth rates in Venezuela. The figure also shows a large variation in labor productivity across countries and sectors. On the aggregate level, Venezuela had a negative average growth rate of -0.83% (in the data) while the average for Korea was 4.42%. For agriculture, most countries had reasonable growth rates. In industry, the rates vary from -1.21% for Venezuela to almost 6% for Korea. Five countries had negative growth rates in services while Chile and Korea had high growth rates.

A final performance test for the model is a summary statistic computed as the average absolute deviations (across countries and over time) between a given time series in the model and in the data (Duarte and Restuccia, 2010). The deviations in percentage points are 0.5 for agriculture, 4.02 for industry, 4.21 for services and 8.64 for aggregate TFP.

The set of figures above and the summary statistic show that the model's predictions are close to the data. In the section below, I discuss the sectoral TFP time series used to achieve these outcomes.

4.1. Comparing Sectoral TFP Paths

In this subsection, I summarize the paths of sectoral TFP relative to the US for the nine countries and highlight the least productive sectors in each country. Figure 6 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 were losing ground to the US. However, since 1970, US agricultural TFP growth was not so high and most countries increased their relative TFPs. The highest productivity growth was for Korea, where relative TFP more than doubled increasing from 14% in 1970 to 39% in 2005. At the other end, Bolivia started with the lowest relative TFP and gained only 4 percentage points relative to the US. While Columbia had a relative TFP slightly higher than that of Korea, its catch-up was the slowest, it gained only 2 compare paths of sectoral TFP points.

As can be seen in panel (B), the relative TFPs for industry started higher than those of the agricultural sector. With the exception of Chile and Korea, all countries fell behind the US in the period. The biggest declines were experienced by Bolivia and Venezuela. While Chile fell behind the US in the 1960-1980 period, it grew fast in the subsequent years and made up the lost ground in the preceding decades. Korea experienced a fast growth during the whole period and approached the level of the US by 2005. The other countries fell behind but to a lesser extent than Bolivia and Venezuela.

Panel (C) shows the time path of relative TFP for services. All countries fell behind the US except Korea, which caught up fast. We see that the declines in the relative productivity of services are consistently higher than the declines observed in industry.

Comparing relative TFPs across sectors show that developing countries considered here are the least productive in agriculture, followed by services, and then industry. While they all started with a very low level of agricultural TFP relative to the US, they experienced from moderate to fast catch-up during the period. Such performance was not experienced in the other two sectors with the exception of Korea and to a lesser extent, Chile. In both industry and services, most countries fell behind the US with larger declines in services. We see from panel (D) that the ratio of relative TFP in services to relative TFP in industry is less than 100% in all countries and it increased only in three countries out of the nine in the sample. This indicates that overall the developing countries considered here have been performing the worst in the service sector over the period 1960-2005.

4.2. Decomposition of Labor Productivity

Following the procedure explained earlier, we can assess the contributions of capital intensity and TFP to the growth of labor productivity in the aggregate economy and the non-agriculture sectors (see table 3). For Argentina, all growth in aggregate labor productivity comes from the capital intensity growth which contributes to 117%. For Bolivia, Chile, Costa Rica, Korea,and Mexico, the largest contributions come from aggregate TFP growth instead. This is a similar pattern for industry. For services, a few countries (Argentina, Bolivia, and Venezuela) had negative average labor productivity growth which all came from TFP. Columbia and Costa Rica had positive growth with 100% of it coming from capital intensity. The strong growth in Chile came mostly from the capital intensity

(69%) while it was the opposite in Korea(41%).

The patterns shown in this table highlight the importance of the decomposition of labor productivity growth. Knowing the sources of growing can help policy makers design and conduct effective policies to increase labor productivity growth. For instance, despite Brazil has an average productivity growth in industry similar to that of Chile (2.23 vs. 2.98), most of its performance comes from increases in capital intensity as opposed to Chile.

5. Discussion of the Findings

As noted earlier, the finding that agriculture is the least productive sector in developing countries is not new, therefore I will not further discuss it here[25]. The main focus of this paper is the comparison between industry and services. Relative to the US, the developing countries considered here are less productive in services compared to industry. This result confirms the finding by Duarte and Restuccia (2010) for labor productivity. In their paper, they use data on sectoral value added growth rates and a similar model to back out PPP-conversion factors across countries. This shows that their finding is robust to the inclusion of capital accumulation. My finding is also consistent with the evidence from micro data. 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 a few developed and developing countries[26]. They find that relative to the US, other countries are less productive in services than industry. 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 highly productive in some services like telecommunications and airlines. Moreover, studies by the Organization for Economic Cooperation and Development (OECD) find similar results for various sub-sectors of industry and services.

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

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

In contrast to the above finding, papers using expenditure data from the Penn World Table (PWT) finds that developing countries have larger sectoral TFP gaps in industry than in services (Herrendorf and Valentinyi, 2012) or larger gap in tradables than in non-tradables (Hsieh and Klenow, 2007). This difference in findings implies that there is a large gap between the differences in producer prices and consumer prices. Notice that my model has implications for producer prices and the findings suggest that the relative prices in agriculture and services are higher in developing countries than in the US. However, the opposite is true from consumer prices from the PWT.

While this paper provides an innovative methodology to circumvent the data limitation for sectoral productivity analysis in developing countries, it makes a few strong assumptions. The first is the assumption of a closed economy. Allowing for openness to trade has two effects on the economy. First, it leads to more competition in the tradable sector, hence it affects sectoral productivities. Second, it affects sectoral prices which has implications for labor reallocation. Increased competition from openness to trade leads non-productive firms to exit and the remaining firms to improve their productivities. With manufacturing producing most tradable goods, this sector may shrink in some countries but it will become more productive relative to the non-tradable service sector. Indeed, McMillan and Rodrik (2012) argue that increased globalization led countries with large endowment in natural resources (mostly from Africa and Latin America) to specialize in that sector, which often is very productive but with a low level of employment, thereby reallocating labor into services, agriculture and the informal sector. However, the destruction of the manufacturing sector because of globalization may leave a country with just non-tradable sub-sectors in industry which are not necessarily more productive than services.

The second effect of trade is on prices. Most models of international trade assume that tradable goods face international prices; therefore price differential will not be linked to productivity differential, hence to labor reallocation across sectors. Numerous tests of the law of one price have shown that it does not hold even within the same country. Thus allowing for trade should not break the link between relative prices and relative productivity. Moreover, my methodology for inferring sectoral TFPs for developing countries does not use data on relative prices. Including trade in the model in a form that creates a wedge between the ratio of industrial TFP to service TFP and their relative prices ($p_s/p_m = A_m/A_s$ versus $p_s/p_m = \omega A_m/A_s$, $\omega \neq 0$) will lead to biased estimates of my inferred relative prices but not the sectoral TFPs.

Overall, the theory predicts that countries with negative trade balances may experience faster de-industrialization, as has been the case for the US (Coleman II, 2007). However, Bah (2013) showed that while this prediction is true for some countries it is not in other countries. He found countries with growing trade balances experiencing fast reallocation of labor out of industry. Therefore, the net effect of trade on the ranking of sectoral TFP is a quantitative question that is unsettled.

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 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 determined. Lastly, the model makes the assumption of no distortions in labor markets and wages are equalized across sectors. Bah (2013) showed that labor distortions are quantitatively important. However, we can back those distortions only if we have data on sectoral TFP. Therefore, we can think that TFPs inferred in this model are the product of true TFP and labor distortions.

The paper also assumes all the investment come from the manufacturing sector. In the past two decades, a large part of investment has been in information technology produced by the service sector. Including this fact in the model can explain in part the rapid decline of manufacturing as the sector is no longer the only source of investment. However, it is difficult to separate aggregate by source even for the US. Moreover including this in model will greatly complicate the solution methodology as it adds a second dynamic equation.

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 1950-2005. Applying the calibrated model to developing countries leads to the finding that relative to the US, developing countries are the least productive in services compared to industry. This finding is the result of countries allocating a larger percentage of their labor force to the service sector rather than industry. The decomposition of labor productivity growth into its components show large variations across-countries and across sectors. Countries with the worst growth performances suffered mostly form low or negative TFP growth rates.

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 industry, investment to output, and capital to output. The data for GDP per capita (*rgdpl*) is from the Penn World Tables (PWT) version 7.0 (Heston et al., 2011) The shares of sectoral hours worked and the price of services relative to industry are from the Groningen Growth and Development Centre (GGDC) 10-sector database (Timmer and de Vries, 2009). 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. Industry 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 industry is deduced form there. This database also contains the sectoral hours worked for the US between 1950 and 1997. For the period, 1998-2005, 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, the employment shares data are obtained from the GGDC 10-sector database and the per capita GDP and investment as a share of GDP (ki) are from the PWT. The total labor force used in the calculation of aggregate TFP is from the World Development Indicator database (World Bank, 2012).

All data series have been filtered using the H-P filter to focus on low frequency trends. The filter was applied before taking any ratios.

A.1. Figures and Tables

Table 1: Statistics in the Data and the Model

Statistics, average 1950-2005	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 / Industry	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: Add caption

	Aggergate economy			Industry		Services	
	Lab. prod.	Cap. intensity	TFP	Lab. prod.	TFP	Lab. prod.	TFP
ARG	0.88	1.04	-0.15	2.00	0.95	-0.08	-1.10
BOL	0.42	0.10	0.33	-0.40	-0.50	-2.01	-2.10
BRA	2.36	1.43	0.93	2.23	0.80	0.91	-0.51
CHL	2.37	1.09	1.28	2.98	1.87	1.59	0.49
COL	1.77	0.90	0.87	1.61	0.70	0.90	0.00
CRI	1.76	0.55	1.20	1.26	0.70	0.55	0.00
KOR	5.72	1.99	3.73	5.66	3.60	4.85	2.80
MEX	2.03	0.99	1.03	1.84	0.84	0.67	-0.32
VEN	0.27	0.73	-0.46	1.09	0.35	-0.96	-1.68
US	1.99	1.04	0.95	1.99	2.46	1.57	0.52

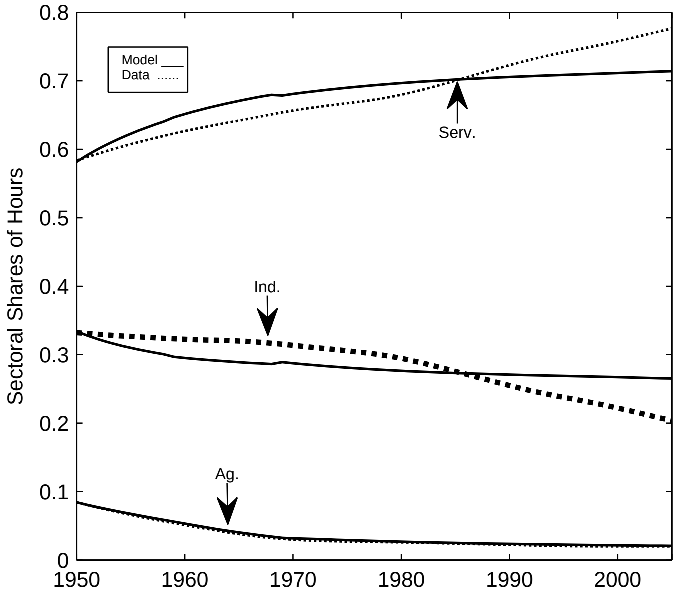

Figure 1: Structural Transformation for the US, 1950-2005-The figure plots the share of hours in the model (solid line) and data (dashed line) for each sector: agriculture, industry and services.

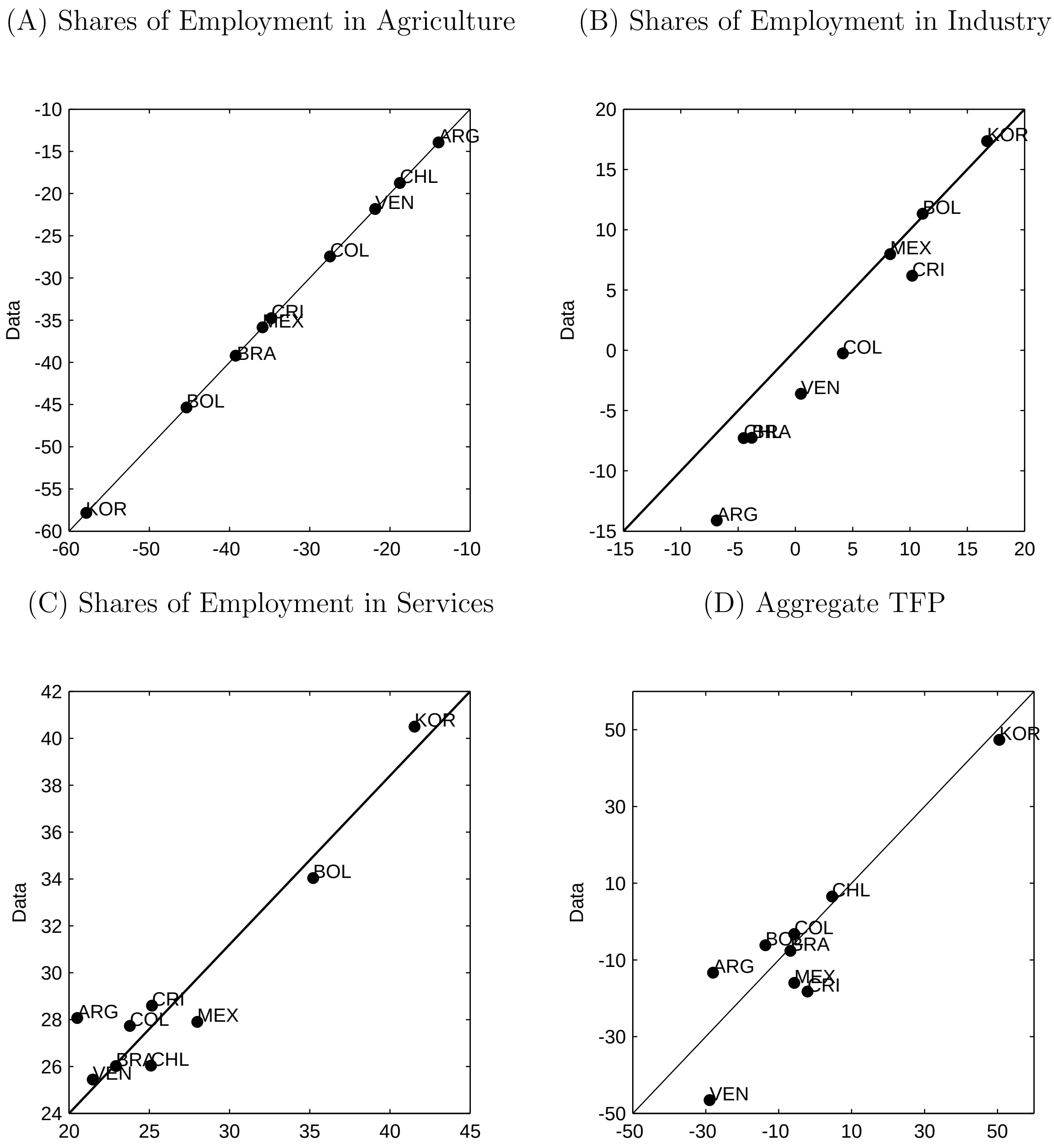

Figure 2: Changes in Employment Shares-Model vs. Data-Each plot reports the change between the last and first period of each variable in the data and in the model (in percentage points).

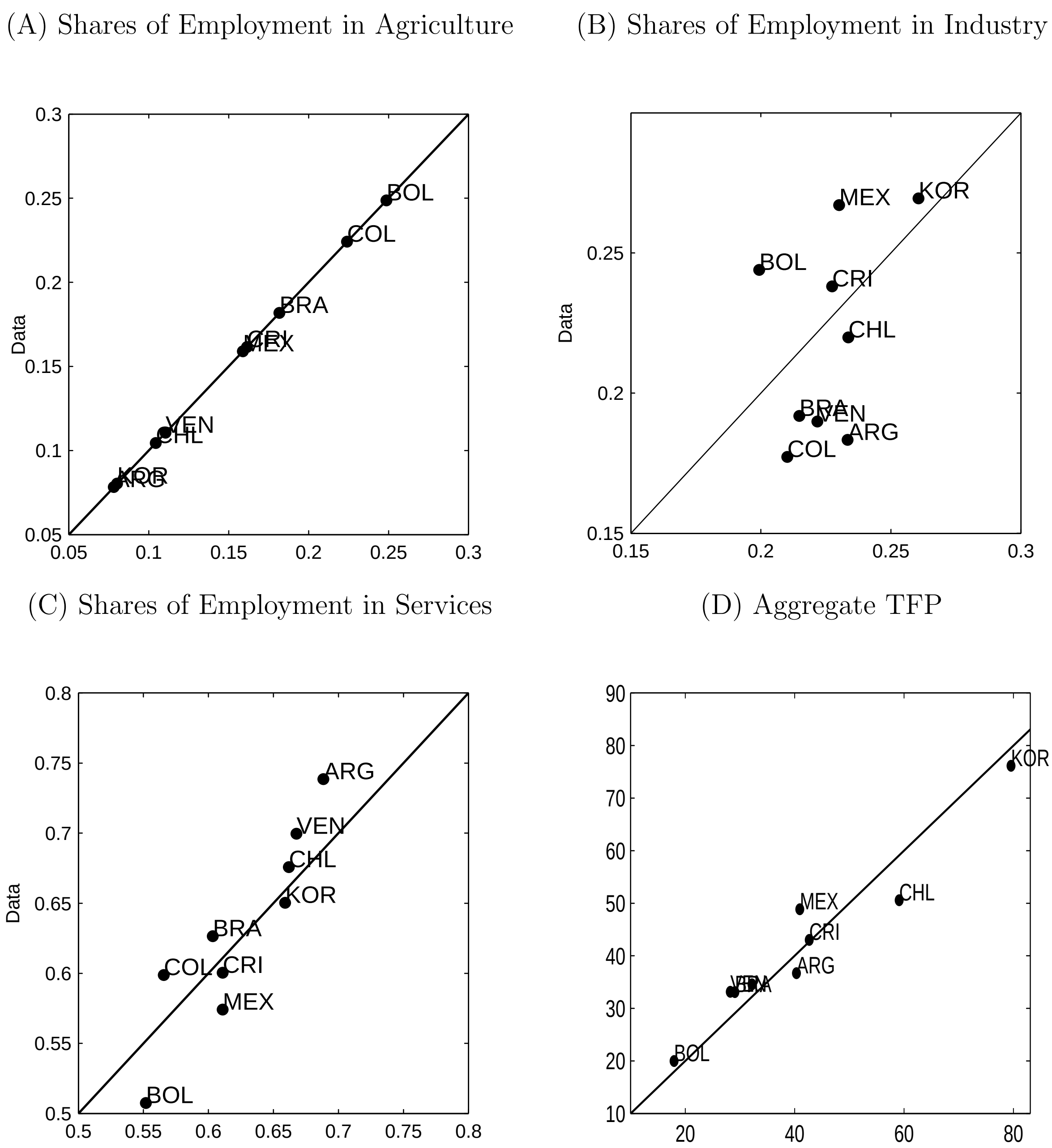

Figure 3: Levels in the Last Year-Model vs. Data-Each plot reports the value in 2005 for each variable in the data and the model (in percentage points).

(A) Relative Per Capita GDP in 1960 (B) GDP per Capita Growth Rates

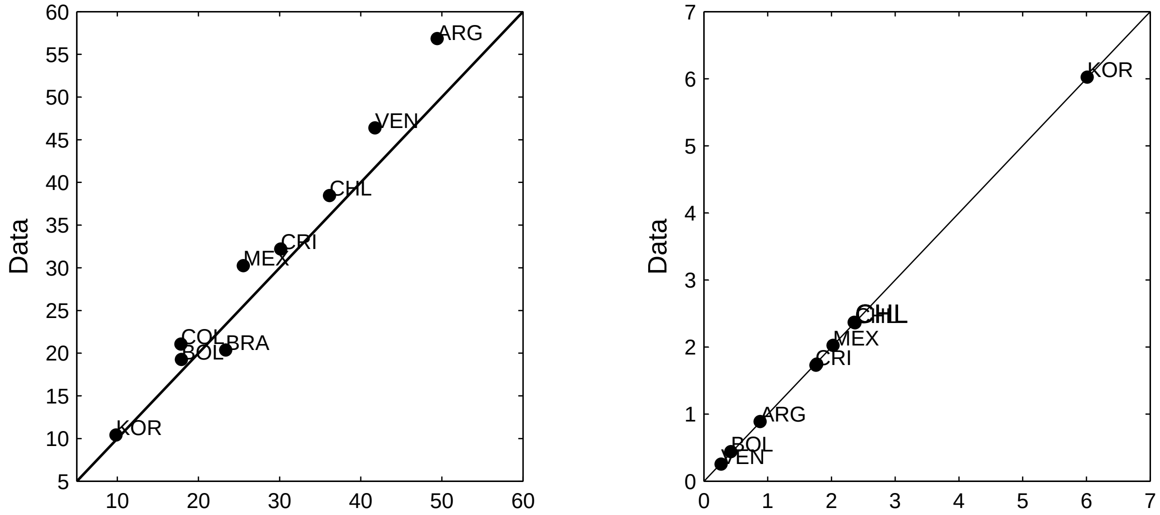

Figure 4: Relative GDP per Capita in 1960 and Growth Rates-Model vs. Data- The first panel reports GDP per capita relative to the US in 1960 and the second panel plots the average growth rate for the period 1960-2005 in the data and in the model.

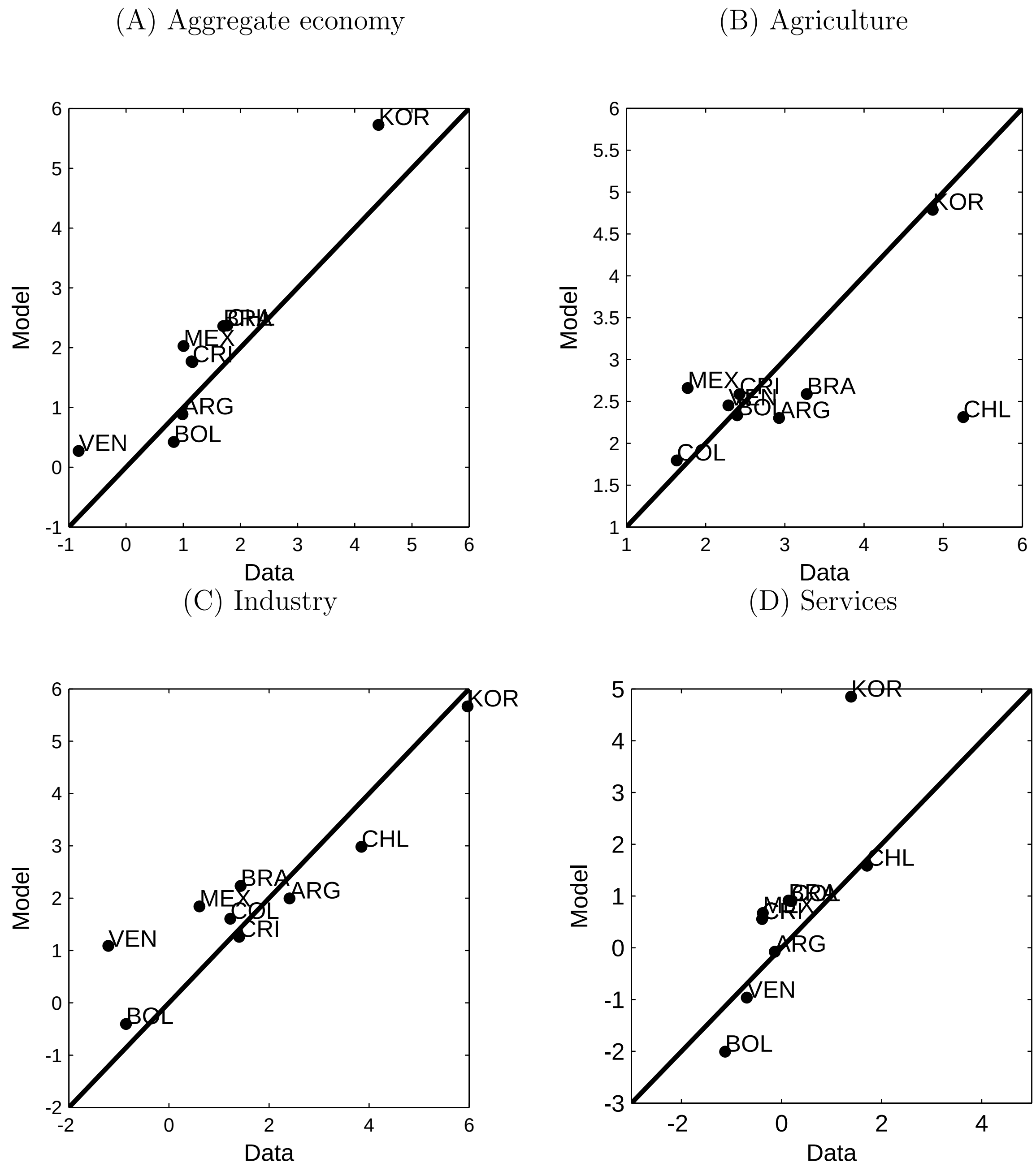

Figure 5: Average labor productivity growth rates-Model vs. Data

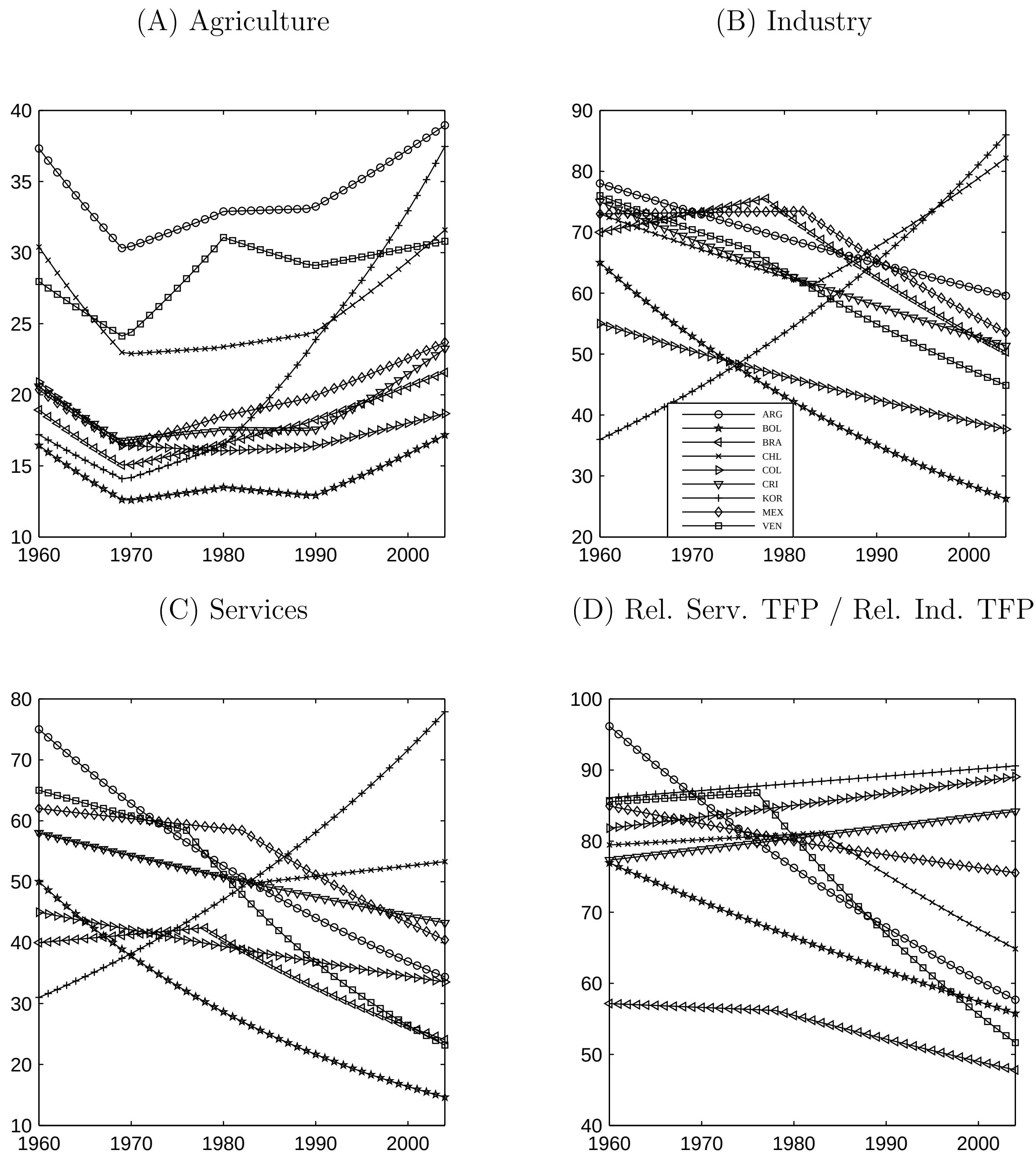

Figure 6: Relative Sectoral TFPs - The first 3 panels plot sectoral TFPs relative to the US in period 1960-2005 and the last panel plots the ratio of relative TFP in services to relative TFP in industry.