Fundação Getulio Vargas

Escola de Pós-Graduacão em Economia

Essays on structural transformation, growth and education

Leonardo Fonseca da Silva

2013

Fundação Getulio Vargas

Escola de Pós-Graduacão em Economia

Essays on structural transformation, growth and education

Tese para obtenção do grau de Doutor em Economia apresentada à Escola de Pós-Graduação em Economia da Fundação Getulio Vargas

Área de concentração: Economia

Orientador: Pedro Cavalcanti Ferreira

Leonardo Fonseca da Silva

2013

Ficha catalográfica elaborada pela Biblioteca Mario Henrique Simonsen/FGV

Silva, Leonardo Fonseca da
Essays on structural transformation, growth and education / Leonardo Fonseca da Silva. – 2013.
94 f.

Tese (doutorado) - Fundação Getulio Vargas, Escola de Pós-Graduação em Economia.
Orientador: Pedro Cavalcanti Ferreira.
Inclui bibliografia.

1. Desenvolvimento econômico. 2. Educação. I. Ferreira, Pedro Cavalcanti. II. Fundação Getulio Vargas. Escola de Pós-Graduação em Economia. III. Título.

CDD – 338.9

FUNDAÇÃO
GETULIO VARGAS

LEONARDO FONSECA DA SILVA

"ENSAIOS SOBRE TRANSFORMAÇÃO ESTRUTURAL, CRESCIMENTO E EDUCAÇÃO"

Tese apresentada ao Curso de Doutorado em Economia da Escola de Pós-Graduação em Economia para obtenção do grau de Doutor em Economia.

Data da defesa: 18/12/2013

Aprovada em:

ASSINATURA DOS MEMBROS DA BANCA EXAMINADORA

Pedro Cavalcanti Gomes Ferreira
Orientador (a)

Carlos Eugênio Ellery Lustosa da Costa

Fernando Augusto Adeodato Veloso

Marcelo Rodrigues dos Santos

Tiago Cavalcanti

Agradeço,

Ao meu orientador, Pedro Cavalcanti, por todo o ensinamento durante o curso de doutorado. Muito obrigado, Pedro, por todo o apoio ao longo de todo esse processo, tive muita sorte em poder contar com você.

Ao meu co-orientador Marcelo dos Santos, pelos momentos que dedicou à minha tese. Pude aprender bastante durante todo esse tempo.

Ao meu chefe Nilson Teixeira, que muito me apoiou e estimulou ao longo do curso de doutorado. Com certeza, não seria possível a conclusão desse curso sem o seu apoio, Nilson, muito obrigado.

Aos meus pais Antero e Lucilia e minha irmã Aline que são a base da minha vida. Muito obrigado pelos momentos de apoio e carinho que sempre pude receber de vocês em toda a minha vida.

À minha namorada Nathallie, por compreender a importância desse curso para minha vida e fazer, dos poucos períodos de lazer nesses últimos anos, momentos muito especiais na minha vida. Muito obrigado.

Aos meus primos Felipe e Luisa, meus tios Beto e Vera e meus avós Antônio e Maria Luisa sempre presentes nos momentos mais difíceis.

Ao amigo Rodrigo Pian, pela força que sempre me passou ao longo desses anos.

Resumo

Esta tese estuda o impacto da transformação estrutural sobre a trajetória de desenvolvimento de economias emergentes. Mais especificamente, busca-se entender de que forma a realocação do trabalho de setores menos produtivos da economia (e.g., agricultura) para setores mais produtivos (e.g., indústria e serviços) contribuiu para o crescimento da produtividade do trabalho nessas economias. A tese é dividida em três capítulos, além da introdução. O primeiro capítulo estuda a relação entre transformação estrutural e desenvolvimento econômico em economias da América Latina. Enquanto que o processo de realocação da mão de obra foi importante para a dinâmica da produtividade no período de convergência dessas economias, a baixa produtividade de alguns setores da economia explicaram a maior parte da redução da produtividade relativa no período mais recente. No segundo capítulo, estudo os principais determinantes do crescimento da economia chinesa entre 1980 e 2005. Mostro que o aumento da corrente de comércio e o forte crescimento da produtividade do setor agrícola contribuíram significativamente para o desenvolvimento chinês no período. No terceiro capítulo, estudo a aparente contradição entre aumento dos níveis de escolaridade e redução da renda per capita nas economias africanas quando comparadas com a economia americana. A principal conclusão é que a redução dos custos educacionais explicaram o recuo do diferencial de educação entre as economias da África e os Estados Unidos.

Abstract

This thesis aims to study the impact of structural change on the trajectory of development of emerging economies. More specifically, we seek to understand how the reallocation of labor from less productive sectors of the economy (e.g., agriculture) to more productive sectors (e.g., industry and services) contributed to the growth of labor productivity in these economies. The thesis is divided into three chapters, besides the introduction. The first chapter studies the relationship between structural change and economic development in Latin American economies. While the process of reallocation of labor was important to the dynamics of productivity in the period of convergence of these economies, low productivity in some sectors of the economy explained most of the reduction in productivity in the most recent period. In the second chapter, I study the main determinants of growth of the Chinese economy between 1980 and 2005. I show that the increased flow of trade and strong productivity growth in the agricultural sector contributed significantly to China's development in the period. In the third chapter, I study the apparent contradiction between increased levels of schooling and reduction of per capita income in African economies compared to the U.S. economy. The main conclusion is that reducing educational costs explain the retreat of the education differential between African economies and the United States.

Contents

1 Introduction **2**

2 Structural transformation and productivity in Latin America **4**

2.1 Introduction 4
2.2 Stylized Facts 7
2.2.1 Data 7
2.2.2 Labor reallocation 8
2.2.3 Aggregate Productivity 10
2.2.4 Sectorial productivity 11
2.2.5 Structural transformation 14
2.3 The Model 18
2.3.1 Equilibrium 20
2.3.2 Calibration 22
2.4 Results 23
2.4.1 Counterfactuals 25
2.4.2 Comparison to South Korea 29
2.5 Conclusion 32

3 Trade, structural transformation and growth in China **33**

3.1 Introduction 33
3.2 Stylized facts 36
3.3 Model 39
3.3.1 General description 40
3.3.2 The household 40
3.3.3 The firms 42
3.4 Calibration 46
3.5 Results 49
3.6 Counterfactual 56

3.7 Conclusion 60

4 Education convergence and growth divergence in Africa 61

4.1 Introduction 61
4.2 Stylized facts 66
4.3 Model 73
4.3.1 Demography 73
4.3.2 Households 74
4.3.3 Technology 76
4.3.4 Government 77
4.4 Recursive equilibrium 77
4.5 Calibration 79
4.6 Simulation 82
4.7 Countefactuals 84
4.8 Conclusion 87

1 Introduction

This thesis aims to study the impact of structural change on the path of development of emerging economies. More specifically, I seek to understand how the reallocation of labor from less productive sectors of the economy (e.g., agriculture) to more productive sectors (e.g., industry and services) contributed to the growth of labor productivity in these economies. Besides this introduction, the thesis is divided into three chapters.

The first chapter examines the impact of structural change on the trajectory of productivity in nine Latin American economies between 1950 and 2005. I use a three-sector (agriculture, industry and services) general equilibrium model calibrated to the main economies in the region. The model very closely replicates labor reallocations across sectors and the growth of aggregate labor productivity from 1950 to 2005. Structural transformation explains a sizeable portion of the region's convergence in the first decades, when there was a reduction in the productivity gap between Latin American economies and the United States. In most cases, the poor performance of the services sector is the main cause of the slowdown in productivity growth observed in the region after the mid-1970s and is a key factor in explaining the divergence during this period.

The second chapter examines the factors that determined the strong growth of the Chinese economy in the post-reform (1980-2005) period. China's recent performance in economic growth was characterized by high investment rate, increase in international trade, strong productivity growth in agriculture and nonfarm sectors and the reallocation of labor across sectors. A standard dynamic general equilibrium model of structural transformation for the Chinese economy is presented to assess the contributions of the main drivers of the Chinese economic development. An external sector is added to the general equilibrium model of structural transformation in order to estimate the contribution of the trade channel to the economic development of China. The contribution of trade to China's economic growth was 26% of total economic growth during the period from 1980-2005. Moreover, the agricultural sector explained 27% of Chinese economic performance from 1980 to 2005.

The third chapter examines the apparent contradiction between increased education levels and contraction of per capita income observed in 31 African economies. Over the past decades, African economies have experienced a significant increase in educational attainment but low growth in GDP per capita, leading to a reduction in the educational gap and an increase in the income gap with respect to the developed countries. To reconcile these facts, a recursive general equilibrium model is calibrated to some African economies. The model considers human capital accumulation as a function of life expectancy, educational costs and productivity gains. The model estimates that most of the increase in education levels in these economies between 1970 and 2008 was explained by the sharp decline in the implicit costs of education. The impact of increases in longevity is modest.

2 Structural transformation and productivity in Latin America

2.1 Introduction

It is commonly accepted that there is a huge disparity in the development experiences of countries around the world. While many nations experienced a rapid increase in output per worker in recent decades, others lost ground compared with the leading economies. Latin America is a well-known case of relative stagnation or divergence. What is most remarkable is that until the mid-1970s, almost all of the economies in the region experienced high productivity growth, reducing the gap with respect to developed economies. However, except for Chile, there was a dramatic decrease in growth after this convergence period, and in most cases, the relative productivity in 2005 is similar or even lower than that verified for 1950. For instance, output per worker for Mexico relative to the U.S. increased from 40% in 1950 to 60% in 1976 but then fell to only 38% in 2005. In Brazil, the movement was similar, with relative productivity increasing from 16% to 33% from 1950 to 1980 but falling to 23% by 2005.

At the same time, a rapid process of structural transformation and a reallocation of labor across sectors can be observed in the region. While the leading countries after WWII were already urban economies with economic activities concentrated in manufacturing and services, most of the countries in Latin America were still rural economies. In Brazil, Mexico and Colombia, for instance, more than 50% of the working population was in agriculture in 1950. In most cases, this allocation was no longer the case by the mid-1970s and by 2005, with very few exceptions, less than 20%-25% of the working population was in the agricultural sector. In contrast, the share of services in the working population and in value added increased markedly in all countries in the region, reaching more than 60% of the total employment in most cases.

Certain aspects of economic development may be linked to this reallocation process. Obviously, aggregate productivity is the sum of sectorial productivities, weighted by the share of workers employed in each sector. Thus, the shift of workers from a less productive sector (e.g., agriculture) to a more productive sector (e.g., manufacturing or services) increases the overall productivity of the economy. However, once this process - or most of it - is completed, the path of overall productivity depends chiefly on the productivity growth of each sector. Hence, the fact that service sector labor productivity in certain Latin American economies fell or slowed dramatically in the 1980s and 1990s, at the same time that the relative importance of the sector increased, may explain a sizeable portion of the region's stagnation.

In this article, we analyze the relative productivity path of Latin American countries from the perspective of structural transformation. Although our data set begins in 1950 and we implement some exercises with the data from the convergence period, our main interest is to investigate the most recent period. More precisely, we want to understand and measure the contribution of the different sectors to the decrease in relative productivity observed in these countries over the last 20 to 30 years.

We use a very simple three-sector general equilibrium model that is calibrated for nine countries in the region. The model very closely replicates labor reallocation across sectors and the growth of aggregate labor productivity from 1950 to 2005. We then perform counterfactual exercises for each country to quantify the relative importance of each sector to the productivity slowdown. For instance, in one exercise we first estimate what the relative productivity would have been had all of the sectors grown over the entire 1950-2005 period at the rates observed during the convergence sub-period. In the case of Brazil, for instance, output per worker would be 56% instead of 23% of output per worker in the U.S. Then, keeping productivity growth in the two sectors constant and equal to the growth during the convergence period, we change the productivity growth in the other sector to that ob-

served in the data. For most economies, by far the strongest impact is due to the decline in the productivity of services. In the case of Brazil, relative output per worker falls from 56% to 32% in the simulation for the service sector and to only 44% in the case of manufacturing.

The relationship between economic development and structural change was first examined by Kuznets (1966) in the mid-1960s and by Chenery (1975), Kuznets (1971) and Rostow (1971) in the early 1970s. In this article, we follow a more recent strand of the literature that combines the influence of international income differences with the delay in the structural transformation process. For example, the works of Duarte and Restuccia (2005), Duarte and Restuccia (2010), and Echevarria (1997) explain the reasons why some countries achieve exceptional increases in productivity while others only widen the productivity gap compared with more developed economies, while Herrendorf and Valentinyi (2012) investigate which sectors make poor countries unproductive.

Numerous studies have examined the recent growth slowdown in Latin America (e.g., Cole, Ohanian, Riascos and Schmitz (2005), Loayza, Fajnzylber and Calderón (2005), Blyde and Fernandez-Arias (2006) and Ferreira, Pessôa and Veloso (2013)). As far as we know, this is the first article to investigate the link between structural transformation and the stagnation in Latin America in the 1980s and 1990s. We find that the sectorial effects are very important to explaining the recent development experience in Latin America, and the performance of the tertiary sector is the key to understanding it.

The paper is organized into four sections in addition to this introduction. In Section 2, we present the main stylized facts on growth and structural transformation in Latin America, including a decomposition based on McMillan and Rodrik (2011). The model and the calibration procedure are presented in Section 3, and in Section 4, the results are presented and discussed. Section 5 concludes.

2.2 Stylized Facts

2.2.1 Data

The main data sources are the Penn World Table and the Groningen Growth Development Centre 10-Sector Database[1]. The period considered is 1950 to 2005 for all countries except Chile, Peru and Bolivia, whose series data are available for only part of the sample[2].

Each sector of activity is defined according to the international standard classification of economic activities in the statistical division of the United Nations (ISIC 3), in which the agricultural sector comprises forestry, fisheries and agriculture; the industrial sector comprises mining, extraction, manufacturing, utilities and construction; and the services sector comprises wholesale and retail, hotels, restaurants, transport, storage, communications, finance, insurance, real estate, personal services, social services, community services and the government.

Some notes regarding the data used in this paper must be highlighted. For some countries, the sectorial employment series in the Groningen database is slightly different from the series found in the official datasets. For instance, the series for sectorial employment in the Groningen database for Brazil replicates the trend observed in the data from the IBGE (the Brazilian statistical bureau), but the level of the series is not the same. For example, both databases show the same decline in the share of employment in the agricultural sector and the increase in the share of employment in the service sector in recent decades. Because we are mostly interested in the trend in the employment data from 1950 to 2005, this difference in the databases is

[1] See Timmer and de Vries (2009). For the United States, the data for employment and value-added are taken from the Bureau of Economic Analysis of the U.S. Department of Commerce.

[2] For Peru, the series data cover the period from 1960-2005. For Chile, the series data cover the period from 1951-2005. For Bolivia, the series data cover the period from 1950-2003.

not a major problem for our analysis[3].

The absolute productivity is calculated as the ratio of the value added in real terms in the currency of each country to the total number of employees in each country. The relative productivity is calculated as the ratio of the absolute productivity of each country, adjusted for Purchasing Power Parity (PPP), to the absolute productivity in the United States, also adjusted for PPP. Because no data are available for the value added adjusted for PPP in each sector, the relative productivity of each sector is determined by the model. We use the general equilibrium model to back out sector-specific PPP conversion factors across countries in the initial period (1950) and use the data on growth rates of labor productivity in local units (constant price) to construct the time series for productivity that we feed into the model.

2.2.2 Labor reallocation

From Figures 1 and 2 it is clear that all Latin American economies experienced a strong process of labor force reallocation, with steep decrease in the participation of agriculture and an increase in the share of labor in services:

[3] Note that the classification of each economic activity is the same for all economies.

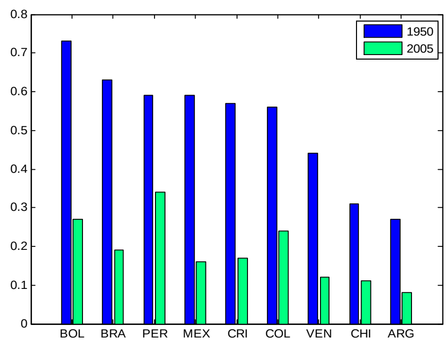


Figure 1: Labor Share in Agriculture

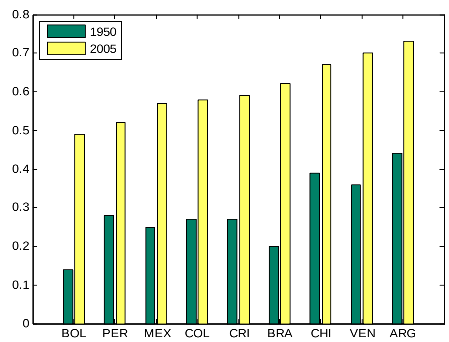


Figure 2: Labor Share in Services

In most cases, these Latin American economies are in an earlier stage of structural transformation compared with developed economies, although each country is going through different phases of the labor reallocation process. In most of the countries (e.g., Brazil, Mexico, Chile and Venezuela), the percentage of workers employed in agriculture was between 10% and 20% in 2005 (Figure 1), but this percentage was less than 10% in some countries (e.g., Argentina, 7.7%) and greater than 20% in others (e.g., Colombia, 24%) during the same period. Likewise, the percentage of workers employed in services in 2005 was close to 70% in certain countries (e.g., Argentina, Chile and Venezuela) and closer to 60% in others (e.g., Brazil, Colombia, Costa Rica and Mexico). In Bolivia and Peru, the share of employees in agriculture in 2003 and 2005 was relatively high (27% and 34%, respectively), and the percentages of employees in the services sector were low (49% and 52%, respectively).

Some countries that had a large share of employees in services and a small share in agriculture in 2005, such as Argentina, Chile and Venezuela, began the process of structural transformation earlier than others. Nevertheless, the composition of labor observed in more developed economies (e.g., the United States) suggests that the process of labor reallocation is likely to

continue in these economies. For example, the share of workers employed in agriculture in the United States was 1.6% in 2005, while the percentage of workers employed in services was 80.9%.

2.2.3 Aggregate Productivity

Growth in Latin America during the period from 1950-2005 can be divided into two parts. Until the middle to the end of the 1970s, the economies in the region experienced high productivity growth, reducing the gap with respect to the developed economies[4]. However, except for Chile, there was a dramatic decrease in growth after this period, and in most cases, labor productivity relative to the U.S. in 2005 was below or close to the 1950 levels.

Table 1 presents Latin American labor productivity relative to the U.S. in 1950, 2005 and in the year in which relative productivity "peaked"[5]. Brazil and Mexico exhibited a strong acceleration in relative productivity from 1950-1980. Relative productivity in Brazil increased from 0.16 in 1950 to 0.33 in 1980, while relative productivity in Mexico increased from 0.40 in 1950 to 0.60 in 1976. In the following years, however, these countries experienced a significant decline in labor productivity, such that relative productivity in 2005 fell to 0.23 in Brazil and 0.38 in Mexico. In other cases, such as in Costa Rica, Peru and Venezuela, there was also a catch-up period in the early years of the sample. However, this process was shorter, lasting only until the early 1970s.

Colombia, unlike the other countries, did not go through a period of productivity convergence between 1950 and 2005. Until 1990, Colombia's relative productivity remained stagnant, with a strong decrease in the following years. In Argentina, relative productivity increased from 0.40 in 1950 to 0.42

[4] Only Venezuela had its catch-up process interrupted before this date, more precisely in 1970. In Bolivia, relative productivity declined throughout the period.

[5] Because our goal is to understand the trend of the relative productivity measure, we use the HP filter to "extract" the fluctuations in the data due to the business cycle. The peak in this case is the maximum value of the relative productivity trend.

in 1975. Despite the small increase in comparison with other Latin American economies, relative productivity exhibited an increase of 4 percentage points during the period from the trough (0.38 in 1955) to the peak of 0.42 in 1975. Among the countries considered, Venezuela exhibited the strongest decline in relative productivity in recent years: relative productivity increased from 0.55 in 1950 to 0.68 in 1970, but then it collapsed to 0.28 in 2005.

The only country that experienced an increase in relative productivity in recent years was Chile. Despite its reduction in the early years of the sample, Chile's relative productivity increased from 0.27 in 1985 to 0.34 in 2005.

Table 1: Relative productivity

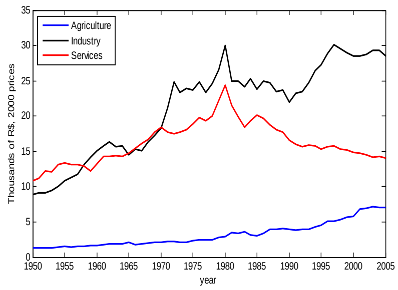
	Relative Productivity			Peak's
	1950	Peak	2005	year
Argentina	0.40	0.42	0.32	1975
Bolivia	0.21	0.21	0.12	1950
Brazil	0.16	0.33	0.23	1980
Chile	0.30	0.35	0.34	2000
Colombia	0.26	0.28	0.19	1976
Costa Rica	0.34	0.45	0.28	1971
Mexico	0.40	0.60	0.38	1976
Peru	0.27	0.34	0.21	1974
Venezuela	0.55	0.68	0.28	1970

2.2.4 Sectorial productivity

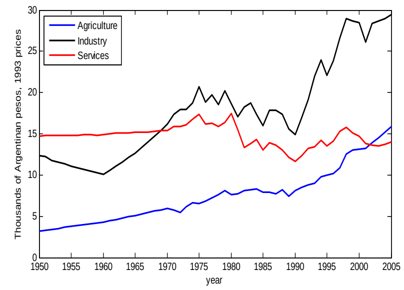
Figure 3 presents the sectorial productivities of six economies. With the sole exception of Venezuela, industrial productivity increased during the entire period in all of the economies. From 1950 to the mid-1970s or 1980, industrial productivity increased very rapidly. From 1950 to 1980, for instance,

manufacturing[6] productivity grew by 4.2% per year in Brazil. In Argentina, manufacturing productivity grew by 2.1% per year from 1950 to 1975, and it grew by 3.1% per year over the same period in Colombia. Similar figures are observed for Chile and Mexico. Note, however, that productivity growth in this period was rapid in all sectors of all countries. This fast and generalized productivity growth, combined with the reallocation of labor across sectors, explains the convergence observed during the period.

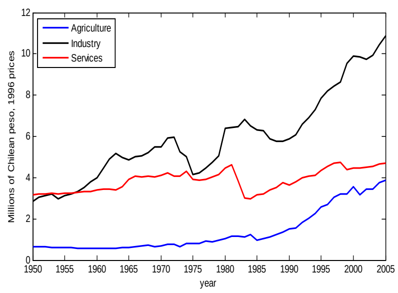
[6] We will use industry and manufacturing interchangeably throughout the paper.



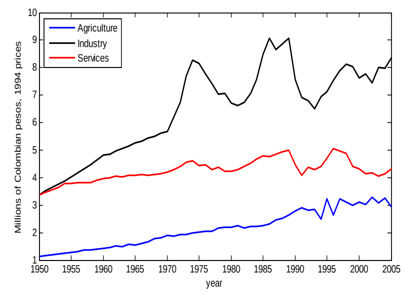
Brazil



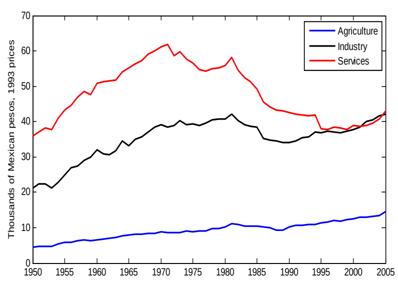
Argentina



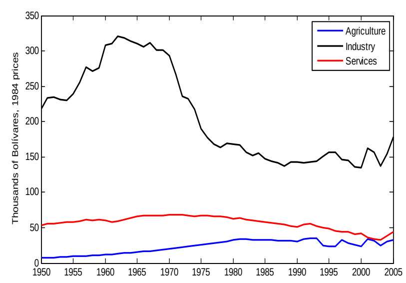
Chile



Colombia



Mexico



Venezuela

Figure 3: Sectorial Productivity in Latin America

A decomposition of the stagnation after the peak years is more subtle. In Brazil, for instance, manufacturing productivity in the 1981-2005

period slowed significantly to 0.6% per year, and productivity growth in services decreased by a shocking -1.7% per year, although the productivity of the agricultural sector continued to grow strongly. Taking into account the reduction in labor share for manufacturing and considering that the labor share for services reached more than 60% of the labor force, it is easy to understand the reversion of the Brazilian catch-up process. After 1975 in Argentina, there was a mild slowdown in manufacturing productivity (from 2.1% to 1.6%), but productivity growth in services was negative (it decreased from 0.6% to -0.5%).

The productivity trends also changed in approximately 1975 for Colombia. Colombia's manufacturing productivity did not grow at all after 1975, and productivity in services declined by -0.1% annually. Agricultural performance was not bad, but if one considers that the labor share for the sector decreased from 56% to 24% between 1950 and 2005, it is obvious that the agricultural sector's impact on overall productivity was small. The Mexican case is similar to Colombia in the sense that after a period of rapid growth, manufacturing and services experienced a strong productivity decline.

Chile is the only country in the sample in which the productivity in services grew over the last two decades. In fact, Chile experienced rapid growth in all three of the sectors during this period, with agriculture reaching an impressive 7.1% per year, manufacturing 2.7% and services 2.0%. Thus, Chile's recent catch-up process was a result of the efficiency of the economy as a whole. In Venezuela, in contrast, all of the sectors contributed to the productivity decline: from 1971 to 2005, the annual growth rates in manufacturing and services were -1.2% and -1.3%, respectively.

2.2.5 Structural transformation

The study of the process of structural transformation is important to understand the different productivity paths in these countries in recent years. As we shall see, the reallocation of labor from agriculture to more produc-

tive sectors (e.g., industry and services) explains a significant share of the productivity gains in several of the Latin American economies between 1950 and 2005. Even in countries that exhibited a strong decline in productivity in some sectors, the reallocation of labor across sectors helped prevent an even greater reduction of productivity in recent years.

A good place to start to understand the contribution of structural transformation on Latin America's growth experience is with the methodology of McMillan and Rodrik (2011). These authors separate aggregate productivity growth into structural factors (e.g., change in technology) and labor reallocation. The methodology consists of decomposing aggregate productivity according to the following equation:

$$\Delta Y_t = \sum_{i=n} \Theta_{i,t-k} \Delta y_{i,t} + \sum_{i=n} y_{i,t} \Delta \Theta_{i,t}$$

where Y_t is the aggregate productivity, $y_{i,t}$ is the productivity in each sector of the economy and $\Theta_{i,t}$ is the sectorial share of employment.

The first term reflects productivity gains that resulted from changes in the technology within each sector, while the second term reflects the productivity gains that resulted from labor reallocation across sectors. Thus, the growth in labor productivity can be broken down into a more structural component (the first term in the equation) and a component associated with the process of structural transformation (the second term in the equation). Table 2 presents the breakdown of average growth in aggregate productivity for the nine Latin American countries under analysis.

Table 2: Breakdown of Productivity gains[7] (%, pp)

	1950-2005			1950-peak			peak-2005		
	Agreg	Tec	Str. Tr.	Agreg	Tecn	Str. Tr.	Agreg	Tecn	Str. Tr.
Brazil	2.3	1.6	0.7	4.7	2.6	2.1	−0.5	−0.7	0.2
Argentina	0.8	1.1	−0.2	1.7	1.3	0.4	0.1	0.5	−0.4
Chile	1.8	1.9	−0.1	1.2	1.1	0.0	2.9	2.9	0.0
Mexico	1.7	0.8	0.9	3.3	1.7	1.6	0.3	−0.2	0.5
Colombia	1.5	1.2	0.3	2.5	2.0	0.5	0.5	0.3	0.2
Venezuela	0.0	0.0	0.0	2.5	1.6	1.0	−1.3	−1.2	−0.2
Peru	1.1	0.7	0.3	3.8	2.4	1.4	−0.1	0.0	−0.1
Bolivia	0.9	0.4	0.5	–	–	–	–	–	–
Costa Rica	1.9	1.5	0.5	4.0	2.8	1.2	0.7	0.4	0.3

The results vary across countries and periods, but we can conclude that the reallocation of labor was an important source of productivity gains for all of the countries from 1950 to 2005. When we consider the period from the peak of relative productivity for a given country to 2005, the process of structural transformation prevented a more significant decline in labor productivity in some countries (e.g., Brazil, Mexico and Colombia) while in other economies, the reallocation of labor contributed negatively to the aggregate productivity of the economy (e.g., Venezuela and Argentina). In Mexico, half of the growth is explained by structural transformation, and in the most recent period, structural transformation more than offset the decline in labor productivity arising from the negative contribution of sectorial technology growth.

In the case of Brazil, the dynamics of productivity changed greatly from 1950-2005. From 1950-1980, there was a strong reallocation of labor

[7] We do not calculate the productivity gains by sub-period for Bolivia because the relative productivity declined throughout the sample. We divided the sample into two sub-periods for Chile: 1950-1986, when relative productivity decreased, and 1986-2005, when there was an expansion of relative productivity.

from agriculture to the fast-growing manufacturing and services sectors[8]. According to the methodology of McMillan and Rodrik (2011), this reallocation of labor explains 44% of the growth during the period (2.1 percentage points). In other words, almost half of Brazil's productivity growth was due to a reallocation of labor across sectors. As noted previously, productivity in services declined and the industrial sector's productivity slowed during the period from 1981-2005 in Brazil. The gains arising from the continued decline in labor's share of the agricultural sector could not offset this sharp decline in productivity in services. The results in Table 4 show that without the process of structural transformation, aggregate labor productivity would have declined even more than it did in 2005 with respect to the peak year.

The reallocation of labor across sectors in Argentina did not contribute as much to productivity growth in its two sub-periods as in Brazil. The first period was characterized by a reduction in the share of employees in the less productive sector of the economy (agriculture), an increase in the labor share in services and relative stability in the industrial sector, and this process explains one-fifth of Argentina's growth. From 1976-2005, there was a labor reallocation from agriculture and industry to services. Because labor productivity in the services sector was much lower than in the industrial sector, the loss of productivity arising from the reallocation of labor from manufacturing to services more than offset the gains arising from the reallocation of labor from agriculture to services. As a result, the contribution of the structural transformation process was negative.

The aggregate productivity of the Chilean economy grew an average of 2.9% per year from 1985-2005, compared with 1.8% per year throughout the entire period. All of the sectors grew at rapid annual rates in recent years: 7.1% in agriculture, 2.7% in industry and 2.0% in services. Growth in Chile did not benefit from the labor reallocation, as Table 4 shows that

[8]The percentage of workers employed in the industrial sector increased from 17% in 1950 to 23% in 1980, while the share of employment in the services sector increased from 20% to 39% during the same period.

all of the productivity gains are explained by factors related to the higher efficiency of the economy as a whole in the most recent period.

The aggregate productivity in Venezuela grew by only 0.05% per year between 1950 and 2005. As in other Latin American countries, the most significant increase in productivity occurred in the beginning of the period (in the case of Venezuela, from 1950-1970), and during this period, structural transformation explains 39% of the productivity gains (1.0 percentage point). In the second sub-period, the aggregate productivity of the Venezuelan economy contracted at an annual rate of 1.3%, and all of the sectors contributed to the lower growth; in fact, the productivity of the sectors decreased at more or less the same rate. Thus, the large decline in Venezuela's relative productivity in the last thirty years can be explained by the inefficiency of its economy as a whole.

2.3 The Model

The decomposition exercise in the last subsection and the other stylized facts presented previously indicate that sector reallocation may be extremely important in explaining Latin America's growth experience. However, this partial equilibrium analysis does not consider several feedback effects that a richer environment may capture. In this section, we present a three-sector general equilibrium model, similar to Duarte and Restuccia (2005) and Rogerson (2005), to decompose and measure the contribution of each sector to the slowdown in labor productivity observed in the region.

The economy is populated by a representative household that lives for infinite periods. Time is discrete and at each time t three items are produced: agricultural good (a), manufactured good (m) and services (s). The production function is given by:

$$Y_i = A_i L_i,$$

for $i \in \{a, m, s\}$, where Y_i is the output in sector i, L_i is the labor allocated to the production sector i, and A_i is the technology employed in each sector i. In addition, the household is provided with a unit time to be supplied inelastically, and the size of the population is normalized to 1.

The household preferences over consumption goods are represented by:

$$\sum_{t=0}^{\infty} \beta^t u\left(c_t, c_{at}\right),$$

where c_{at} is the consumption of the agricultural good at t and c_t is the consumption of a composite of industrial goods and services at the date t. The utility function is given by:

$$u\left(c_t, c_{at}\right) = \log\left(c_t\right) + V\left(c_{at}\right),$$

where $V\left(c_{at}\right)$ is characterized by:

$$V(c_{at}) = \begin{cases} -\infty, \text{ when } c_a < \bar{a} \\ \min\left\{c_a, \bar{a}\right\}, \text{ when } c_a \geq \bar{a} \end{cases}$$

i.e., the household cares only about consuming the subsistence level of agricultural good. The composed good, c_t, is given by:

$$c_t = \left[b c_{mt}^{\rho} + (1-b)\left(c_{st} + \bar{s}\right)^{\rho}\right]^{\frac{1}{\rho}},$$

where $\bar{s} > 0$, $b \in (0,1)$, and $\rho < 1$. The parameter $\bar{s}$ can be interpreted as the home production of services.

There is a continuum of firms in each sector, operating in perfect competition in the factor and production markets. The problem of the representative firm, at each date t, given prices and wages, is:

$$\max_{L_i \geq 0} p_i A_i L_i - w L_i, \tag{1}$$

where L_i is the demand for labor in sector i.

After solving the firm's problem, we can write the representative household problem for each date t as:

$$\max_{c_i \geq 0} \log \left[b c_m^{\rho} + (1-b)\left(c_s + \bar{s}\right)^{\rho} \right]^{\frac{1}{\rho}} + V\left(c_a\right) \tag{2}$$

$$s.a$$

$$p_a c_a + p_m c_m + p_s c_s = w.$$

The market clearing conditions are:

1. Supply and demand for labor must be equal at each date t:

$$L_a + L_m + L_s = 1. \tag{3}$$

2. All production will be consumed in each of the three sectors:

$$c_a = Y_a,\ c_m = Y_m,\ c_s = Y_s. \tag{4}$$

2.3.1 Equilibrium

A competitive equilibrium for this economy is a set of prices $\{p_a,\ p_m,\ p_s\}$, consumption allocations $\{c_a,\ c_m,\ c_s\}$, and labor allocations $\{L_a,\ L_m,\ L_s\}$, such that:

1. Given prices $\{p_a,\ p_m,\ p_s\}$, the labor allocations for the firm $\{L_a,\ L_m,\ L_s\}$ solve (1).

2. Given prices $\{p_a,\ p_m,\ p_s\}$, the consumption allocations for the household $\{c_a,\ c_m,\ c_s\}$ solve (2).

3. Market Clearing: (3) and (4) must be satisfied.

Normalizing the wage at 1, we arrive at the following first order conditions for the firm's problem:

$$p_a = \frac{1}{A_a}; \qquad p_m = \frac{1}{A_m}; \qquad p_s = \frac{1}{A_s}. \tag{5}$$

That is, for the three sectors of the economy the price of each good is inversely related to the productivity of the sector.

To find the demands for the three goods, we must take the first order conditions of the household problem. First, note that by the definition of the function $V(c_a)$, we have that $c_a = \bar{a}$, i.e., the consumption of the agricultural good for the household will always be the subsistence level $\bar{a}$. Solving (2), we have:

$$\frac{\frac{1}{\rho}\left[bc_m^{\rho} + (1-b)(c_s+\bar{s})^{\rho}\right]^{\frac{1}{\rho}-1} \rho b c_m^{\rho-1}}{\left[bc_m^{\rho} + (1-b)(c_s+\bar{s})^{\rho}\right]^{\frac{1}{\rho}}} = \lambda p_m \tag{6}$$

$$\frac{\frac{1}{\rho}\left[bc_m^{\rho} + (1-b)(c_s+\bar{s})^{\rho}\right]^{\frac{1}{\rho}-1} \rho (1-b)(c_s+\bar{s})^{\rho-1}}{\left[bc_m^{\rho} + (1-b)(c_s+\bar{s})^{\rho}\right]^{\frac{1}{\rho}}} = \lambda p_s, \tag{7}$$

where λ is the Lagrange multiplier. Dividing (6) by (7)we find:

$$\frac{b}{1-b}\left(\frac{c_m}{c_s+\bar{s}}\right)^{\rho-1} = \frac{p_m}{p_s}. \tag{8}$$

With equation (8) and the market clearing conditions we have:

$$L_m = \frac{(1-L_a) + \frac{\bar{s}}{A_s}}{1 + \left(\frac{b}{1-b}\right)^{\frac{1}{\rho-1}} \left(\frac{A_m}{A_s}\right)^{\frac{\rho}{\rho-1}}}, \tag{9}$$

and $L_a = \frac{\bar{a}}{A_a}$. We use the previous expression in the above equation to find L_m and then L_s using market clearing condition in the labor market.

2.3.2 Calibration

In our strategy, we first calibrate a benchmark economy (in this case, the U.S.). We then use some of the preference parameters of this economy in addition to equilibrium conditions of the model and some targets to calibrate the Latin American economies.

We must select values for the parameters b, ρ, $\bar{a}$ and $\bar{s}$ as well as time series for the relative productivity in each sector, $A_{i,t}$, for $i \in \{a, m, s\}$, so that the model can replicate the main observations on employment in each sector over the period from 1950-2005. Using the equilibrium relationships of the model, we calculate the relative productivities in each sector of the Latin American economies in 1950[9]. In the following years, productivity grows at the rate of growth of the sectorial productivities observed in the data. Denoting α_i as the annualized growth rate of productivity in sector i, the path for productivity in the three sectors for the following years is $A_{i,t+1} = (1 + \alpha_i) A_{i,t}$, where α_i is given by $\alpha_i = \left(\frac{A_{i,05}}{A_{i,50}}\right)^{\frac{1}{55}} - 1$.

The preference parameters b, ρ, $\bar{a}$ and $\bar{s}$ are obtained by the equilibrium equations of the model. The parameter $\bar{a}$, which can be interpreted as the subsistence level of consumption of the agricultural product, is chosen to match the share of employment in agriculture in 1950. The value of $\bar{s}$ is selected to match the employment share in manufacturing in 1950. Thus, given the values of b and ρ, we find $\bar{s}$. The parameters b and ρ are chosen jointly to approximate the paths (from 1951 to 2005) of the labor share in manufacturing and the aggregate productivity growth generated by the model with those observed in the data.

Note that in the case of the U.S. economy, the calibration strategy does not require that the path of employment in manufacturing predicted by the model and the observed data be exactly the same. In the case of

[9] The sectoral productivities for the U.S. economy are normalized to 1 in 1950 so that the sectoral productivities of the Latin American economies are measured relative to the U.S. economy.

the Latin American economies, these series are, by construction, exactly the same. The value for parameter b is selected as the better fit between the series of employment share in manufacturing predicted by the model and the series observed in the data[10].

The table below describes the values for each parameter and the variable used as a target in the calibration.

Table 3: Parameters of the model

Parameter	Value	Target
$A_{i,50}$	1.0	Normalization
$\{A_{a,t}\}_{50}^{05}$	{.}	Productivity growth in Agriculture
$\{A_{m,t}\}_{50}^{05}$	{.}	Productivity growth in Industry
$\{A_{s,t}\}_{50}^{05}$	{.}	Productivity growth in Services
$\bar{a}$	0.05	Employment in Agriculture in 1950
$\bar{s}$	0.95	Employment in Industry in 1950
b	0.02	Employment in Industry from 1951 to 2005
ρ	-1.5	Aggregate labor productivity growth

2.4 Results

The model satisfactorily replicates the process of structural transformation in most of the economies in the region, as can be seen in Figure 4.

[10] For the Latin American economies, we follow the approach used by Duarte and Restuccia (2005), who added a time-varying wedge in non-market activities in the services sector in Portugal so that the model was able to exactly replicate the path of the employment share in manufacturing during the period. This wedge could represent an increased role of taxes and other regulations in the market economy.

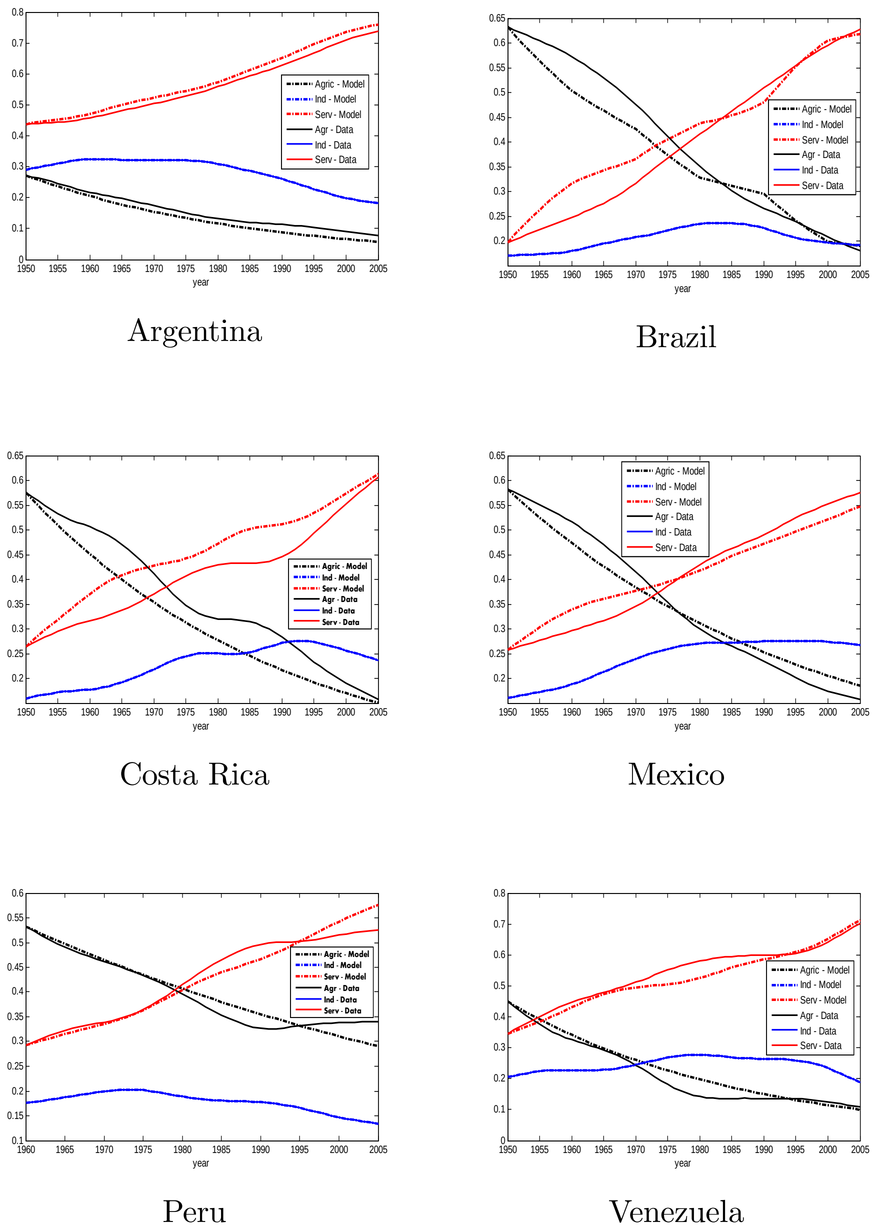


Figure 4: Employment share by sector - Model vs data

The model is also able to reproduce the path of aggregate productivity. Figure 5 displays the simulation for the Brazilian case ("Model") and the data (observed data - hp), which were filtered with the Hodrick-Prescott filter. As is clear from the picture, once we feed the sector productivities into the model simulation, we are able to reproduce the inverted U-shaped path of aggregate productivity in Brazil, matching the peak and the slopes very closely. In the next section, the model is used as a tool to decompose the productivity among sectors.

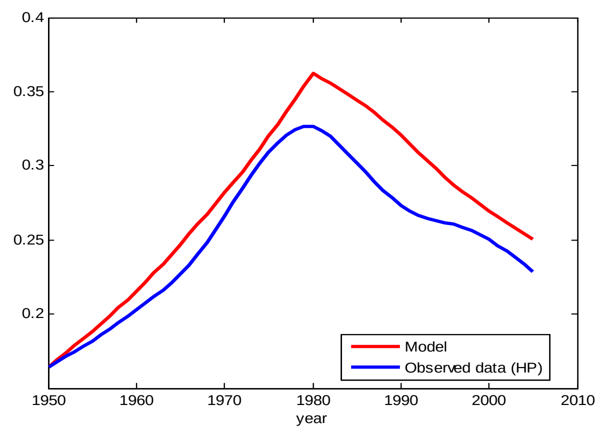


Figure 5: Relative Productivity, Brazil

2.4.1 Counterfactuals

In this section, we perform counterfactual experiments with the Latin American economies calibrated above. The goal is to quantify the productivity gains resulting from hypothetical scenarios. We focus on six economies that underwent a period of convergence of labor productivity and subsequently exhibited a decline in relative productivity.

In the first exercise, the sectorial productivities of all of the economies continue to grow at the same rates observed in the convergence period[11]. For

[11] The convergence periods for each country are as follows: Argentina, 1950-1975; Brazil,

instance, we estimate what would have been the relative productivity for Brazil in 2005 if the productivity growth in the three sectors between 1981 and 2005 had increased at the same rates as they increased from 1950-1980. This result is used as a benchmark for the other exercises. The results are presented in the Benchmark column in Table 4.

Table 4: Relative Productivity (w/ growth rates of the convergence period)

	1950	2005				
		Observed	Simulated			
			Benchmark	Agric.	Manuf.	Services
Argentina	0.40	0.32	0.38	0.37	0.35	0.29
Brazil	0.16	0.23	0.56	0.56	0.44	0.32
Costa Rica	0.34	0.28	1.07	0.41	0.59	0.76
Mexico	0.40	0.38	0.85	0.81	0.69	0.64
Peru	0.27	0.21	0.49	0.49	0.46	0.23
Venezuela	0.55	0.28	0.72	0.67	0.60	0.39

The results suggest that the Brazilian economy would have undergone a rapid process of convergence if it had maintained its productivity growth rates of 1950-1980 in the subsequent period. The relative productivity would have increased from 16% in 1950 to 56% in 2005, which is much higher than what was actually observed in 2005 (23%). Costa Rica would have surpassed the U.S., and Mexico and Venezuela would also have converged to output levels that were close to those of the leading economies.

There are general equilibrium factors at work here. The productivity gains are derived from the fact that productivity growth in services and industry remains high in the period from 1980-2005. Because productivity in the industrial sector grows relatively faster than in services, there is a large

1950-1980; Mexico, 1950-1976; Costa Rica, 1950-1971; Venezuela, 1950-1970; and Peru, 1950 to 1974.

shift of labor from manufacturing to services. Thus, it is essential that the productivity growth in services remains high; otherwise, the shift of labor from manufacturing to services would decrease Brazil's relative productivity. Hence, the economy would have grown faster not only because each sector is growing faster but also because labor reallocation would occur faster than observed, and labor would migrate to sectors in which absolute productivity would now be even higher.

In a second group of counterfactual exercises, productivity growth in two of the sectors (e.g., agriculture and industry) are kept constant and equal to those in the convergence period, and we change the productivity growth in the other sector (e.g., services) to be the same as in the period of decline in relative productivity. Thus, this exercise is similar to the previous counterfactual, except in one of the sectors, the rate of productivity growth in the most recent years of the sample is changed to be equal to that observed in the data. Thus, we are now measuring the contribution of each sector to the decline in (aggregate) relative productivity[12].

In all cases except Costa Rica, the contribution of the services sector in the productivity slowdown is the highest. For instance, relative productivity would fall from 56% to only 32% if Brazil's services sector had grown at the observed rates in the second period, while the other sectors continued to grow at their rates during the convergence period. In the case of manufacturing, the drop is considerably smaller, to only 44%. In Peru, almost the entire productivity decline is explained by the services sector, similar to Argentina and Venezuela, although less so in both cases. In these three cases, labor productivity would remain very close to the benchmark simulation if the growth rate of manufacturing was changed to its growth rate in the previous period. In most cases, the contribution of agriculture is negligible, either because its growth rate was similar in both periods (e.g., in Brazil) or

[12] As before, in the initial subperiod - the convergence years - we keep the rates of productivity growth in each sector constant and equal to those observed in this period.

because the relative size of the sector was already small (as in Argentina).

In this exercise, we identified two channels affecting aggregate productivity when the rate of growth in services is changed by the rate observed in the period of productivity decline. There is a direct effect of a smaller growth rate of productivity and an indirect effect of labor reallocation. In the last case, lower productivity growth in services increases the labor share of the sector and consequently reduces the labor share in manufacturing, the sector in which absolute and relative productivity are the highest. Thus, the decline in relative aggregate productivity is even more intense.

Another way to understand the impact of the reallocation of labor to the services sector, which showed smaller gains in productivity compared with the other sectors, would be to analyze the trajectory of the relative productivity of the Latin American economies if there had been no structural transformation in the second period. That is, what would have been the productivity dynamics if the share of workers in each sector had remained constant after the peak? In the case of Brazil, the relative productivity would have been 0.27 in 2005, higher than that implied by the model (0.25) when we allowed the growth rates of labor productivity in each sector to be equal to those observed in the data. The absence of a reallocation of labor to the sector with less productivity gains in the economy would imply a higher relative productivity than when we allow for the reallocation of labor.

In this case, the exercise indicates that structural transformation negatively contributed to the evolution of relative productivity in the most recent period. Although the exercises are not directly comparable - in the case of the McMillan and Rodrik decomposition, we used absolute productivity - this simulation reinforces the previous results that the productivity gains arising from the structural transformation were concentrated in the period of convergence. In the subsequent period, when there was a contraction in relative productivity, the reallocation of labor from agriculture to the other sectors of the economy did not prevent the drop in productivity caused by

the decline in productivity in services.

If our model had considered capital in the production function, sectorial productivity changes would obviously imply a reallocation of capital among the sectors. This movement suggests that our model underestimates the reallocation of labor across sectors: the marginal productivity of capital would increase (decrease) when the TFP in, say, services increased (declined), attracting (expelling) capital to this sector and raising (reducing) the production of the sector even more.

2.4.2 Comparison to South Korea

Similar to Latin America, South Korea experienced a rapid process of structural transformation in the second half of the last century. In 1965, almost 60% of South Korea's labor force worked in agriculture and less than 30% in services. Forty years later, the share of the labor force in agriculture was less than 10%, and the share in services was more than 60%. However, unlike Latin America, South Korea experienced rapid and continuous convergence to the productivity levels of the leading economies: from 1965 to 2005, labor productivity increased at an annual rate of 4.3%, and in the same period, its productivity relative to the U.S. increased from 0.14 to 0.52. In addition to faster productivity growth in the manufacturing sector (at a rate of 5.9% per year), productivity in the services sector showed an upward trend during the entire 1965-2005 period, growing at 1.5% per year. In contrast, manufacturing and services grew in Brazil by 1.7% and -0.1%, respectively, during the same period.

It would be interesting to determine the performance of the Latin American countries had the structural transformation process in the region occurred under South Korean sectorial productivity rates. We perform this estimation by implementing three counterfactual simulations for the same six economies of Table 4. For each of these countries, we retain the productivity growth rate in the second period ("divergence") in two sectors as in the data,

and we change the growth rate in the remaining sector to that of the corresponding sector in South Korea. Thus, in the "Agriculture" simulation in Table 5, the growth rates of manufacturing and services are kept as observed in the data after the peak, but the growth rate of agriculture is changed to that of South Korea.

Table 5: Relative Productivity (Counterfactual with S. Korean growth rates)

	1950	2005			
		Observed	Simulated		
			Agriculture	Manufacture	Services
Argentina	0.40	0.32	0.28	0.37	0.44
Brazil	0.16	0.23	0.26	0.37	0.39
Costa Rica	0.34	0.28	0.48	0.77	0.61
Mexico	0.40	0.38	0.54	0.87	0.66
Peru	0.27	0.21	0.26	0.31	0.39
Venezuela	0.55	0.28	0.32	0.50	0.65

Despite substantial productivity growth in South Korea's manufacturing sector, the productivity gains are not as large as one might expect when we equate the rate of productivity growth in this sector in Brazil to that of South Korea. This result is due to the reallocation of labor from manufacturing to services, which grew at a negative rate of -1.7% in the period from 1981-2005, so the productivity gains obtained from higher productivity growth in the industrial sector are offset by lower productivity levels and growth in the services sector. The relative productivity of the Brazilian economy would have increased to 26% in the case in which we equalize Brazil's agricultural productivity growth rate to South Korea's, to 37% in the case of manufacturing and to 39% for the counterfactual for services. Thus, this counterfactual suggests that even with strong productivity growth in the industrial sector, the Brazilian economy would not be able to maintain the

rapid productivity convergence because of the low efficiency of the tertiary sector. Because services experienced the largest increase in the working population during the period under study, a sharp increase in relative aggregate productivity would not occur without high productivity growth in services.

Similarly, for the other 3 economies - Argentina, Peru and Venezuela - the isolated impact of services is stronger than that of the other two sectors, reinforcing the results of the previous simulations. In the case of Peru and Venezuela, if the service sector had grown in the second period at the South Korean rates, their economies would be twice as large as observed in the data. In contrast, if the industrial sector in Mexico had grown at the same pace as that of South Korea, Mexico's relative productivity would have been 87% of the US's productivity, so Mexico would have almost converged to the productivity level of the leading economy.

Figure 6 presents the results of one last simulation.

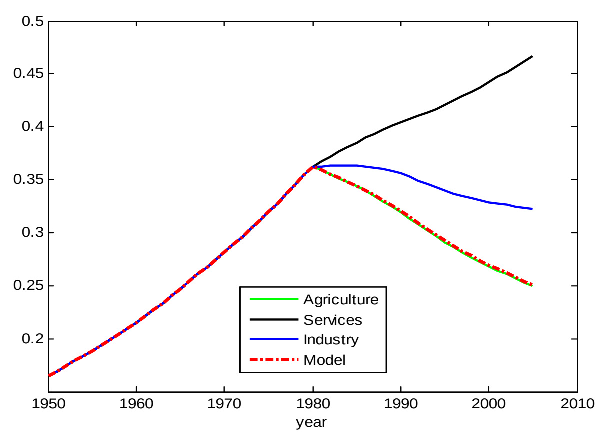


Figure 6: Relative productivity in Brazil

As in the exercises above with South Korean data, we kept the productivity growth rate of two sectors constant and equal to the observed data

for the period from 1980 to 2005 and changed the growth rate in the remaining sector to that of the previous period, when Brazil was rapidly converging. We compared that result with the full simulation ("Model"), when all of the sectors grew at the observed rates.

This counterfactual exercise strengthens the results presented above. If productivity growth during the divergence period in the services sector was equal to that of the convergence period, aggregate productivity in Brazil would have increased to 45% of that of the U.S. in 2005, which is much higher than the actual data and the full simulation. By changing the productivity growth rate in the industrial sector to the growth rate of the convergence period (and holding everything else constant), relative aggregate productivity would increase to just 32% of the U.S. productivity, while in the agriculture simulation, the trends are virtually the same. Thus, this counterfactual reinforces the role of the services sector in driving the productivity path of the Brazilian economy in recent decades.

2.5 Conclusion

This study analyzed the trajectory of aggregate productivity in Latin America during the period from 1950-2005. A common pattern in most of the economies examined was the increase in relative productivity during the early years of the sample - partly explained by structural transformation - followed by a strong reversal in subsequent years. In some countries, relative productivity in 2005 was lower than in 1950. In many cases, such as Brazil and Peru, the relative inefficiency of the services sector when compared with the developed nations - and the low growth rates of the sector in recent years - contributed significantly to the reversal of the productivity convergence.

Latin American economies are still in the process of reallocation of labor across sectors. The persistence of the inefficiency of services will likely hurt future growth in the region and prevent faster convergence of output levels - or any convergence at all - close to those of the leading nations.

Despite the limitations imposed by the use of a fairly simple model of structural transformation, the main contribution of this work was identifying which sectors hastened or retarded the process of productive growth in Latin America. The next step is to examine the causes behind the inefficiency of the tertiary sector. A starting point may be the flow of low-skill labor from agriculture and industry to services, which has occurred in almost all Latin American countries. Thus, a model of structural transformation that incorporates human capital accumulation and occupational decisions would be a good first attempt to address this problem.

3 Trade, structural transformation and growth in China

3.1 Introduction

China's recent performance in economic growth has been unique. The country experienced a long period of stagnation followed by one of extremely rapid growth. For instance, if we extrapolate the trends exhibited over the previous decade, China will overtake Japan in 16 years in per capita terms. Only 16 years ago, China's GDP per capita was less than 15% of that in Japan. Since 1978, China's per capita GDP has grown at more than 7% annually, arguably the "most sustained period of rapid economic growth in human history" (Naughton, 2007).

One possible interpretation is that until 1979, when institutional and economic reforms began, the country suffered from a "malthusian trap", with stagnation or extremely slow growth. Since 1980, China has experienced "modern growth", characterized by rapid growth and convergence with the developed world. This is compatible with "Barriers to Riches" theory (Parente and Prescott, 2000), which states that institutional or political barriers prevent growth. It is also compatible with "Unified Growth" theories (e.g.,

Hansen and Prescott (2002), Galor and Weil (2002)), and hence China would be experiencing its own industrial revolution.

In addition to the significant acceleration of growth, other factors also characterized the development of the Chinese economy in recent decades. International trade has increased significantly with the sum of exports and imports increasing from less than 9% of GDP in the seventies to close to 60% at present. Capital accumulation in the nonagricultural sector increased substantially, and the growth of Total Factor Productivity (TFP) was significant in the agricultural sector. Furthermore, there was reallocation of labor from the agricultural sector to nonagricultural sectors, which allowed greater gains in aggregate productivity of the economy in the period.

This environment was conducive to a significant acceleration of economic growth in China. Labor productivity in the nonfarm sector was higher than in the agricultural sector in part because nearly all capital accumulation in the economy has occurred in the former sector. The implementation of economic reforms, which led to the reallocation of labor across sectors, and the high TFP growth in the agricultural sector fostered China's economic growth.

The objective of this article is to quantify the contributions of the main drivers of Chinese economic growth, namely: a high investment rate, the strong productivity growth in each sector and the reallocation of labor across sectors. To do so, we present a standard dynamic general equilibrium model of the structural transformation of the Chinese economy. In our model, labor reallocation across sectors is a consequence of our assumption, common to standard models of structural transformation, that the income elasticity of the agricultural good is less than unity[13].

The literature on the structural transformation of the Chinese economy is extensive. Several articles, e.g., Birchenall and Cao (2013), Dekle and

[13]This assumption ensures that the model is able to replicate Engel's law, a finding in economics stating that as income rises, the proportion of income spent on food falls, even if actual expenditures on food increase.

Vandenbroucke (2012) and Brandt and Zhu (2010), have examined the role of the reallocation of labor across sectors during the reform period, when the Chinese economy experienced high growth rates. While most articles assign substantial importance to the process of labor reallocation from agriculture to other sectors of China's economy, the conclusions regarding the magnitude of this contribution are mixed. For example, Brandt and Zhu (2010) conclude that high TFP growth in the nonagricultural sector was the main driver of Chinese growth, while Birchenall and Cao (2013), however, note that the rapid TFP growth in the agricultural sector was responsible for the pattern of strong output growth in the Chinese economy.

Our paper differs from other contributions to the literature by adding an external sector to the general equilibrium model of structural transformation. In models of closed economies, the difference in total factor productivity growth between the agricultural and nonagricultural sectors is an important driver of the trend in the relative price of the agricultural good. A higher (lower) rate of TFP growth in the agricultural sector relative to TFP growth in the nonagricultural sector implies a decrease (increase) in the relative price of the agricultural good. As a result, closed economy models tend to overestimate the reallocation of labor from agriculture to the nonfarm sector. In contrast, open economy models, which assume that the relative price of the agricultural good is exogenous, can suitably replicate the reallocation of labor across sectors observed in the post-reform period. This follows from the observation that the relative price of the agricultural good, measured by the ratio of the deflators in rural and urban areas, remained relatively stable from 1980 to 2005, unlike the path of the relative price of the agricultural good forecasted by the closed economy model.

The article is organized into six sections in addition to this introduction. In the next section, we present stylized facts that will guide our analysis, while Section 3 presents the model. In Section 4, we discuss the calibration procedures, while sections 5 and 6 present results and counterfactual

simulations. Finally, Section 7 concludes.

3.2 Stylized facts

Certain stylized facts characterize the development of the Chinese economy in recent years, for example, the significant growth in China's per capita output. The figure below presents China's GDP per capita from 1929 to 2011, using World Development Indicators (WDI) data. It is clear from the figure that until the end of the seventies (and since at least 1929) China grew at an extremely slow rate. The rate of economic growth accelerates thereafter. Relative to the USA, China's GDP per worker increased from 3.4% in 1979 to 19.8% in 2007. China's TFP increased from 20% of US TFP in 1980 to 60% in 2007 (3.9% per year).

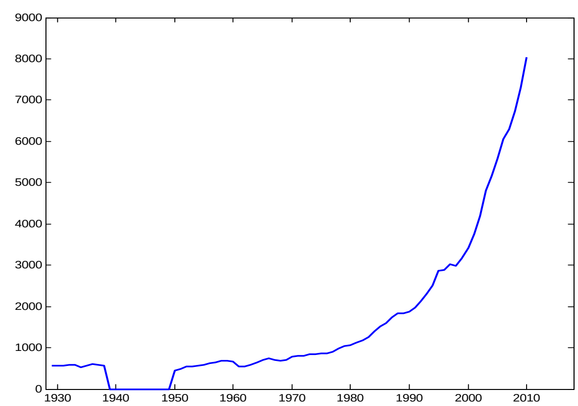


Figure 1: GDP per capita (US$ current)

A striking feature of the Chinese economy between 1980 and the present is the rapid capital accumulation over the period. This was only possible because of the high savings rate in the Chinese economy throughout the period. For example, the savings to GDP ratio increased from 36% in 1982

to 52% in 2011. However, this high savings rate is a recent feature of the Chinese economy. In the early years following China's economic reforms, the savings to GDP ratio increased from 36% in 1982 to 43% in 1994 and decreased to 37% in 2000. The savings to GDP ratio has only increased significantly in recent years, from 2001 to 2011.

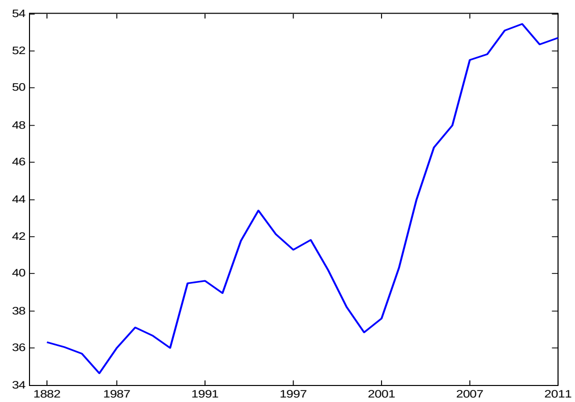


Figure 2: Savings as percentage of GDP

China experienced a rapid growth in foreign trade during the period considered, which coincided with accelerated growth. From the figure below, one can see that trade was relatively stagnant until 1979, and thereafter that both imports and exports grew continuously. For instance, the measure of the Chinese economy's trade openness (which considers the sum of imports with exports) increased from 5.3% of GDP to 58.7% in 2011, with exports accounting for 31.4% of GDP and imports 27.3% of GDP in 2011.

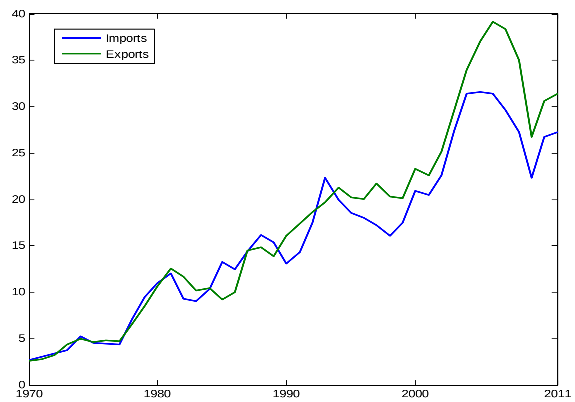


Figure 3: Imports and exports (% of GDP)

The employment share of Agriculture fell from approximately 80% in 1960 to 71% in 1978, 60% in 1990 and less than 50% in approximately 2005. However, it is still considerably higher than in other countries experiencing "economic miracles", and the rural population remains in the majority: according to the WDI (2009), in 2008 only 43% of the population lived in urban areas, compared to 56% in South Korea in 1980, when its GDP per capita was similar to that of China today[14]. As the percentage of workers employed in agriculture is still high compared to other emerging economies, this process of reallocation of labor across sectors of activity is likely continue to be an operative force in the development of the Chinese economy in the coming years. However, in terms of value added, China's structural transformation is far more advanced, and only 10% of value added in the country is from agriculture, compared to 40% in 1960. However, the share of total value added from industry remained nearly constant during this period and much higher than what is observed for other emerging economies.

[14] A possible explanation is the legal limits on rural-urban migration still present in China.

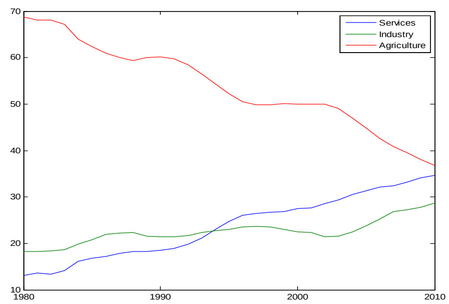


Figure 4: Employment per sector (% of total)

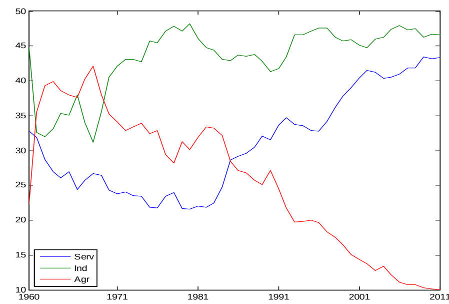


Figure 5: Value added per sector (% of GDP)

Thus, the changes in the Chinese economy between 1980 and the present stand out: strong growth in per capita output, which was made possible by the significant productivity growth during the period considered; high capital accumulation, due to the high savings rate in the economy; the openness of the economy, which led to a growth in exports that exceeded import growth; and, finally, the productivity gains arising from the labor relocation process, present during the development of most economies, which allowed the displacement of labor from less productive sectors (agriculture) to higher productivity sectors (manufacturing and services).

3.3 Model

In this section, we provide a brief description of the standard structural transformation model and define the equilibrium for both closed and open versions of the model. The next step is to calibrate the structural parameters of our theoretical economy and simulate paths for prices and aggregates of this economy during the post-reform period of the Chinese economy (from 1980 to 2005). Using the calibrated model, we perform some counterfactual

exercises to estimate the contribution of the agricultural sector to the path of aggregate output.

3.3.1 General description

Time is discrete with an infinite horizon $t = 0, ..., \infty$. The representative household is provided with one unit of time per period. Household preferences are defined over two goods: a farm good a and a nonfarm good m (manufacturing and services). The representative household is endowed with one unit of labor time, which is supplied inelastically. Of its labor income, in each period the household decides how much to consume of each good and how to divide its savings between capital and land. The price of the agricultural good is denoted by p_t. The stock of land is fixed at 1 and is owned by the household. The nonagricultural good is produced using capital and labor, with capital depreciating at rate δ, and the agricultural good is produced with capital, labor and land (which does not depreciate, is priced at q_t and its rent is r_l). Good a is exclusively used for consumption, while good m is used for consumption and capital accumulation.

3.3.2 The household

The household's preferences are characterized by:

$$\sum_{t=0}^{\infty} \beta^t \left[\gamma \ln (c_{mt}) + (1-\gamma) \ln (c_{at} - \bar{c}_a)\right] \tag{10}$$

where c_{at} and c_{mt} are the flows of consumer goods, and $\bar{c}_a$ is the subsistence level of the agricultural good. This assumption is in line with the literature on structural transformation (e.g., Duarte and Restuccia, 2005) and is used here to ensure that the model can match the share of workers employed in the agricultural sector in 1980. As noted above, this assumption makes the income elasticity of the agricultural good less than 1, i.e., the higher the income of the representative household, the lower the share of the household

budget spent on food. In each period, the household budget constraint is given by:

$$c_{mt} + p_t c_{at} + s_{t+1} = w_t + (1 + r_t)\, s_t \tag{11}$$

where s_{t+1} is household savings in period t.

Is straightforward to demonstrate that the first order conditions for the household's problem are as follows:

$$[c_{mt}] : \beta^t \frac{\gamma}{c_{mt}} = \lambda_t$$

$$[c_{at}] : \beta^t \frac{1-\gamma}{c_{at} - \bar{c}_a} = \lambda_t p_t$$

$$[s_{t+1}] : 0 = \lambda_t - \lambda_{t+1}\,(1 + r_{t+1})$$

where λ_t is the Lagrange multiplier associated with the budget constraint in period t. Manipulating the above equations, we have the following relationships:

$$\frac{c_{mt}}{p_t c_{at}} = \frac{\gamma}{1-\gamma}\left(1 - \frac{\bar{c}_a}{c_{at}}\right)$$

$$\frac{c_{mt+1}}{c_{mt}} = \beta\,(1 + r_{t+1})$$

The first equation demonstrates that when consumption of the agricultural good increases, spending on the nonfarm good increases more rapidly

than spending on the agricultural good. The last equation is the standard Euler equation, which relates the choice of how much of the nonagricultural good to consume in periods t and $t+1$.

3.3.3 The firms

The technology in the agricultural sector is such that the firms in the agricultural sector combine labor n_a, land l and capital k_a to produce an agricultural good denoted y_a. In this economy, the supply of land is assumed to be fixed, and its total size is normalized at 1. The technology in the agricultural sector is given by:

$$y_{at} = z_{at} k_{at}^{\mu} n_{at}^{\phi} l^{1-\mu-\phi}$$

where $\mu, \phi \in (0,1)$ and $\mu + \phi \in (0,1)$.

In the nonagricultural sector, the firms only combine labor n_m and capital k_m to produce a manufactured good denoted y_m. The technology in this sector is given by:

$$y_{mt} = z_{mt} k_{mt}^{\alpha} n_{mt}^{1-\alpha}$$

where $\alpha \in (0,1)$ is the share of capital. The variables n_{it} and k_{it} $(i = a, m)$ represent the employment and capital stocks in sector i. The variables z_{mt} and z_{at} are exogenous and represent the Total Factor Productivity of each sector.

Firms behave competitively to maximize their profits, taking the wage rate w, the rental rate for capital $r_k\,(= r_t + \delta)$, and the rental rate for land r_l as given. Formally, the firm's problem in each sector can be written as follows:

$$\max_{k_{at},n_{at}} y_{at} - (r_t + \delta)k_{at} - w_t n_{at} - r_t l \quad (12)$$

$$s.t.\ y_{at} = z_{at} k_{at}^{\mu} n_{at}^{\phi} l^{1-\mu-\phi}$$

$$\max_{k_{mt},n_{mt}} y_{mt} - (r_t + \delta)k_{mt} - w_t n_{mt} \quad (13)$$

$$s.t.\ y_{mt} = z_{mt} k_{mt}^{\alpha} n_{mt}^{1-\alpha}$$

The first order conditions for profit maximization are:

$$\alpha z_{mt} k_{mt}^{\alpha-1} n_{mt}^{1-\alpha} = r_t + \delta$$

$$p_t \mu z_{at} k_{at}^{\mu-1} n_{at}^{\phi} = r_t + \delta$$

$$(1-\alpha)\, z_{mt} k_{mt}^{\alpha} n_{mt}^{-\alpha} = w_t$$

$$p_t \phi z_{at} k_{at}^{\mu} n_{at}^{\phi-1} = w_t$$

In addition, the rental fee of the land can also be calculated as:

$$(1-\mu-\phi)\, z_{at} k_{at}^{\mu} n_{at}^{\phi} = r_{lt}.$$

Combining the above equations, we have:

$$\frac{n_{mt}}{n_{at}} = \frac{1-\alpha}{\alpha}\frac{\mu}{\phi}\frac{k_{mt}}{k_{at}} \tag{14}$$

The equation above defines an efficient condition for the allocation of inputs (k_{at}, n_{at}), given the stock of capital k_{mt} and the labor share n_{mt} in period t. This relationship defines the allocation of labor and capital in each sector and, given an initial capital stock and the law of motion of capital, defines how much capital and labor are allocated to each sector for all periods of the simulation.

In addition to the equations derived from the representative household's problem and the profit maximization of firms, the following conditions must be satisfied:

$$s_{t+1} = k_{at+1} + k_{mt+1} + q_t$$

$$1 + r_{t+1} = \frac{r_{lt+1} + q_{t+1}}{q_t}$$

The first equation indicates that the savings of the representative household can be allocated to capital in the agricultural sector, capital in the manufacturing sector and land. The land price is denoted q_t. In the second equation, we have the no-arbitrage condition between the two assets (capital and land) where the gross rate of return should equal the gross return of land. In addition, we have implicitly assumed that the rate of return on physical capital should be identical in the two sectors.

Given these considerations, the following equilibrium definitions for closed and open economies of the model are necessary:

Definition 1 *An equilibrium of the closed economy is given by a sequence of prices* $\{w_t,\, r_{kt},\, r_{lt},\, q_t\}$ *and allocations for firms* $\{k_{at},\, n_{at}\}$ *and* $\{k_{mt}, n_{mt}\}$

and the household $\{c_{mt},\ c_{at},\ s_{t+1}\}$ *such that:*

1. The sequence $\{c_{mt},\ c_{at},\ s_{t+1}\}$ maximizes (10) subject to (11) given prices.

2. $\{k_{at}^{*}, n_{at}^{*}\}$ solves (12), given prices, in every period.

3. $\{k_{mt}^{*}, n_{mt}^{*}\}$ solves (13), given prices, in every period.

4. Markets clear:

$$s_{t+1} = k_{t+1} + q_t$$

$$1 + r_{t+1} = \frac{r_{lt+1} + q_{t+1}}{q_t}$$

$$c_{at} = y_{at} \tag{15}$$

$$c_{mt} + k_{mt+1} + k_{at+1} = y_{mt} + (1 - \delta)(k_{mt} + k_{at}) \tag{16}$$

The open economy assumption implies that the relative price of the agricultural good is determined on international markets, implying that it will be determined exogenously to the model. In this case, we assume that the domestic economy behaves as a small open economy that takes the price $p_t = \bar{p}$ as given, and therefore, any surplus (deficit) in the market for good m (or good a) is absorbed by international trade. In this economy, market equilibrium conditions ((15) and (16)) do not need to be satisfied in equilibrium any longer. Thus, the firm's problem in the open economy model is maximize the output subject to the inputs allocation. The equilibrium definition for the open economy is given as follows:

Definition 2 *Given the international price* $\bar{p}$*, an equilibrium path for the open economy is given by a sequence of prices* $\{w_t,\ r_{kt},\ r_{lt},\ q_t\}$ *and allocations for firms* $\{k_{mt},\ n_{mt}\}$ *and the household* $\{c_{mt},\ c_{at},\ s_{t+1}\}$ *such that:*

1. The sequence $\{c_{mt},\ c_{at},\ s_{t+1}\}$ maximizes (10) subject to (11) given prices.

2. $\{k_{at}^{*}, k_{m}^{*}, n_{at}^{*}, n_{m}^{*}\}$ is a solution to the following maximization problem:

$$\max_{k_{at}, n_{at}} p_t z_{at} k_{at}^{\mu} n_{at}^{\phi} + z_{mt} k_{mt}^{\alpha} n_{mt}^{1-\alpha}$$

subject to

$$\frac{n_{mt}}{n_{at}} = \frac{1-\alpha}{\alpha} \frac{\mu}{\phi} \frac{k_{mt}}{k_{at}}$$

$$n_{mt} + n_{at} = 1$$

3. The aggregate capital and the price of land are given by the following laws of motion:

$$s_{t+1} = k_{t+1} + q_t$$

$$1 + r_{t+1} = \frac{r_{lt+1} + q_{t+1}}{q_t}$$

3.4 Calibration

In this section, we calibrate the main parameters of our economy in accordance with the values estimated in the literature and certain targets in the data. We will follow the standard approach in the literature on structural transformation in China and employ estimated values obtained from the literature for both the share of factors in the output of the Chinese economy and the parameters of the utility function. Furthermore, we use the same procedure in the case of the parameters that are calculated to match a given target in the data. The main parameters values were selected as follows:

The total factor productivity in the nonfarm sector in the first period of the simulation, z_{m_1}, was normalized at unity. TFP in the agricultural sector in the first period of the simulation, z_{a_1}, was selected to match the employment share of agriculture at the beginning of the simulation and $\bar{c}_a$, the minimum consumption of the agricultural good, was based on the estimates in the literature as in Brandt and Zhu (2010). We obtained a value of 0.53

for the former and 0.50 for the latter.

The parameters μ and ϕ and are, respectively, the factor shares of capital and labor in the agricultural sector. We observe values for ϕ in the literature ranging from 0.38 and 0.76, and we obtained 0.50 based on estimates in Brandt and Zhu (2010). For the capital share in the agricultural sector, we selected 0.20, which is similar to estimates obtained by Birchenall and Cao (2013) and Chow (1993) and higher than the 0.12 found by Dekle and Vandenbroucke (2011). The depreciation rate δ is 0.05, while the value of β is 0.97. Those are values commonly used in the literature.

For the factor shares in the nonagricultural sector, α is equal to 0.50, the same value for the labor share in the sector. This value is in line with many estimates found in the literature, which indicates a value close to 0.54. We choose $\gamma = 0.85$ such that, in the long run, the share of employment in the nonagricultural sector is 85%.

In addition to the selection of values for the structural parameters, we need to calibrate a value for the initial capital stock (k_1) of the economy. As our model is calibrated to match the share of workers in agriculture in the initial period of the simulation, using equation (14) and the initial capital stock, we are able to find the ratios of capital per worker in the two sectors of the economy. The value of k_1 is selected such that the capital output ratio was equal to 1.62 (Brandt and Zhu, 2010), as observed in the data.

Table 1: Estimates of the structural parameters

Parameter	Value	Target
β	0.97	Based on literature
$\bar{c}_a$	0.50	Brandt and Zhu (2010)
γ	0.85	Long run share of employment in the nonfarm sector
α	0.50	Share of capital in the nonagricultural sector
μ	0.20	Share of capital in the agricultural sector
ϕ	0.50	Share of labor in the agricultural sector
δ	0.05	Depreciation rate
z_{m1}	1.0	Normalized
z_{a1}	0.53	Share of employment in agriculture in 1980
γ_a	6.2%	Growth of TFP in the agricultural sector
γ_m	2.5%	Growth of TFP in the nonagricultural sector

While the divergence of the estimates of the structural parameters of the standard model of the structural transformation for the Chinese economy are not significant, with the range of the estimates from other articles suggesting low dispersion of these values, the estimated values for TFP growth in the farm and nonfarm sectors exhibit high dispersion.

A problem that arises in the estimation of these rates results from the incorporation of human capital in the production function of each sector of the economy. Because it is characterized by a lower level of education than the nonagricultural sector, estimated TFP growth in the agricultural sector tends to be underestimated, as by not incorporating human capital in the production function, we implicitly assume that output in the agricultural sector is generated with an educational distribution identical to that in the nonfarm sector. Vast improvements in access to education has occurred in recent years, and these improvements were likely more beneficial to the production of nonfarm goods, the production of which is more educationally intensive relative to the agricultural good. In this sense, failing to consider

this effect will lead us to underestimate TFP growth in the agricultural sector relative to the nonagricultural one.

For example, Young (2003) estimated a TFP growth of 1.4% in the nonagricultural sector for the period from 1978 to 1998 by incorporating human capital in the production function of this sector. Following the same methodology as Young (2003), Birchenall and Cao (2013) estimated that TFP growth in agriculture was 6.5% for the period from 1978 to 2007. The values for the TFP growth in each sector suggested by the literature range from 3.7% to 6.5% in agriculture and 1.4% to 4.6% for the non-agricultural sector. We selected a TFP growth rate in the agricultural sector of 6.2% and one of 2.5% in the nonagricultural sector, values compatible with the more recent articles that incorporate human capital in the production functions of both sectors.

As we will show below, the TFP growth values in each sector do not significantly change the qualitative results of our analysis, assuming that the TFP growth in the agricultural sector is higher than in nonagricultural sector, as is the case for the vast majority of articles in this literature. The different growth rates of TFP change the extent to which our calibrated model adheres to the data. However, if we assume a TFP growth rate in the nonagricultural sector higher than that in the agricultural sector, the qualitative results would change significantly.

3.5 Results

The economy is simulated for 25 periods to capture the main features of the Chinese economy between 1980 and 2005. We define 1985 as the first period of the open economy; hence the simulations between 1980 and 1985 are made in the closed economy, and from 1985 to 2005, we simulate the model for both open and closed economies and compare the results.

In the simulations with an open economy, we need to define the level of the relative price of the agricultural good that was observed during the

period from 1985 to 2005. We start noting that there is a relative stability - which can be observed comparing the behavior of the deflators in the rural and urban areas, for instance - of the relative price between agricultural and nonagricultural goods during this period. Data does not indicate any clear upward or downward trend.

It is important to emphasize this point. In our model, the elasticity of substitution between agricultural and nonagricultural goods is less than 1, implying that an increase in the demand for the agricultural good is smaller than the increase in its supply, leading to a decline in the relative price of the agricultural good in the closed economy. This decline in relative prices increases the speed at which labor is reallocated from agriculture to the nonfarm sector, making the transfer of labor across sectors faster than that observed in the data. In the case of the open economy, taking into account the fact that the relative price of the agricultural good has remained relatively stable over the period, the transfer of labor occurs at a slower pace than in the case of the closed economy and is consistent with what is observed in the data.

From 1980 to 1984, the model is simulated for the closed economy only; and for both economies from 1985 onwards. This procedure is due to the fact that relative price data is only available after 1985. Given that we know that relative price was relatively stable after 1985, we set the price of the open economy in 1984 equal to that of the closed economy and kept it constant after this.

As we can see from the figure below, the path for the relative price of agricultural good in the open economy more accurately replicates the values observed in the data over the simulated period. As noted above, the closed economy model implies a decline in the relative price of the agricultural good in this period and a faster reduction in the share of workers in the agricultural sector compared to the open economy model.

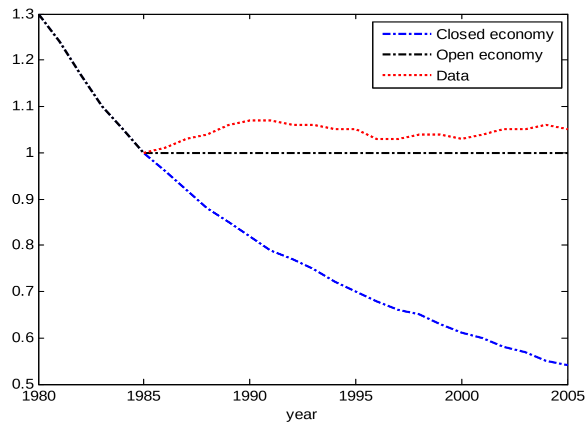


Figure 6: Relative price of agricultural good

The open economy model is able to replicate the path of the labor share in agriculture from 1980 to 2005. The figure below demonstrates that the reallocation of labor between the agricultural and nonagricultural sectors occurs more slowly in the open economy, suggesting a greater role for trade than what is usually credited in the literature. The model simulations for the open economy yield a decline in the share of employees in agriculture similar to the level observed in the data ($0.24pp$).

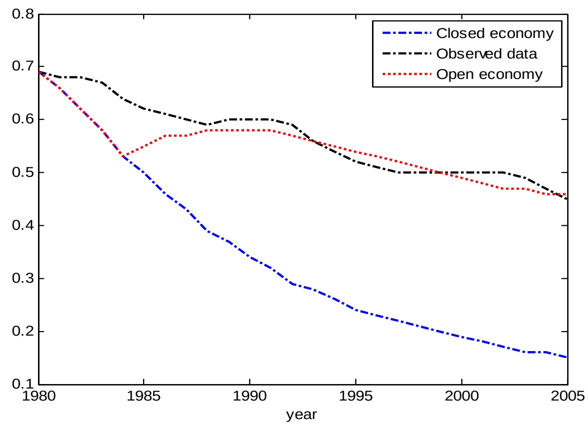


Figure 7: Employment share in agriculture

In the simulations using the closed economy, the reallocation of labor from the agricultural sector to the nonagricultural sector occurs more rapidly than what is observed in the data, meaning that the share of workers employed in agriculture in 2005 is much lower than what was actually observed in the data (15% versus 45%). Note that the speed of labor reallocation from one sector to the other depends on, among other factors, total factor productivity growth rates in each sector. The higher the TFP growth in the agricultural sector relative to that in the nonagricultural sector, the faster will be this shift. This is important due to the large disparity between the TFP growth rates estimated for each sector of the Chinese economy. However, assuming that TFP growth in agriculture is more rapid than the TFP growth in the nonagricultural sector, as it is the case for the majority of the articles in the literature, the qualitative results of the model remain unchanged, as the transfer rate of workers from the agricultural sector to the nonagricultural sector is larger in the closed economy.

For example, the figure below depicts the results of our open economy model for the case in which the TFP growth rates in the agricultural and non-agricultural sectors are 6.2% and 3.2%, respectively, as in Brandt and

Zhu (2010). Moreover, we depict the case where TFP growth in agriculture (3.7%) is lower than in the nonagricultural sector (8.8%[15]), as in Dekle and Vandenbroucke (2011). In this case, the model would better conform to the data in the closed economy, as the reallocation of labor from agriculture to the nonfarm sector occurs faster in the open economy. This result is explained by the fact that, in the open economy, the problem of selecting the share of workers employed in agriculture that maximizes the total output of the economy would lead to an outcome of less production in the more inefficient sector. This is another indication, given the observed growth of trade in China, that TFP growth in agriculture was higher than in the rest of the economy.

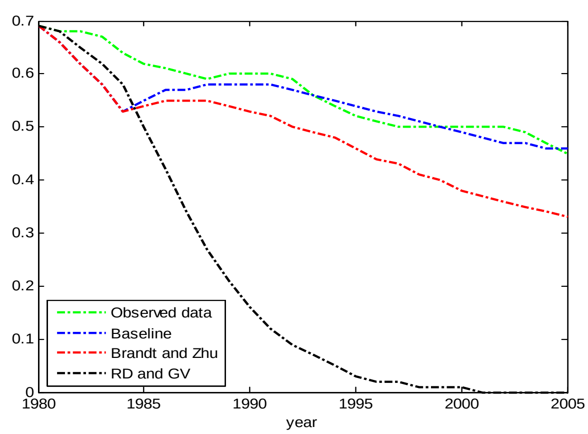


Figure 8: Employment in Agriculture (% of total employment)

The model can also capture other facts observed during the Chinese economy's period of strong growth reasonably well. An important aspect men-

[15]In this case, we consider the TFP growth rate in the nonagricultural private sector. As noted in many articles in the literature on China's structural transformation, the TFP growth rate in the nonagricultural state sector is much lower than the TFP growth rate in the nonagricultural private sector. By failing to consider this fact, our estimates of the growth rate in the nonagricultural sector are upward biased.

tioned above is the trade path. In the figure below, we depict the dynamic of the total flow of trade (imports plus exports as a percentage of GDP) predicted by the model and the values observed in the data. The model is able to replicate the initial trend of the trade path in the Chinese economy reasonably well, but it does not replicate the upward trend observed in recent years. Is important to highlight that China joined in the World Trade Organization only in 2001, and the openess of the economy was not homogeneous among the sectors, with the reduction in the tariffs of some sectors occuring more faster than in others. For example, we can highlight the introduction of a tariff-rate quota system that brought the tariff rate for key agricultural commodities almost to zero for a significant volume of imports and the opening of critical service sectors such as telecommunications and banking to foreign direct investment.

Another important aspect to note is the behavior of savings as a percentage of GDP predicted by the model. We can see from the right hand figure that the closed economy model underestimates the path of savings throughout the period, especially in recent years, in which there was an increase in this measure. The open economy model tends to overestimate the behavior of the saving rate in the most recent period, which explains the relative stability of total trade to GDP ratio in the period.

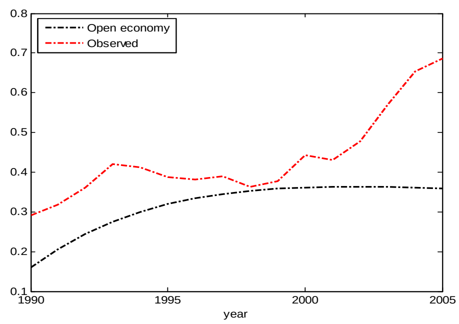


Figure 9: Total trade as % of GDP

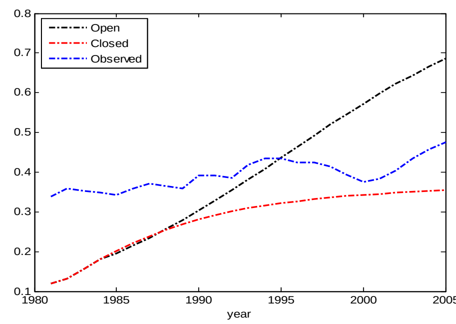


Figure 10: Savings as percentage of GDP

The model is able to replicate many other facts observed in the Chinese economy over the period 1980-2005, for example, the significant growth rates of the capital stock, output growth in the agricultural and nonagricultural sectors and the reallocation of labor from agriculture to the nonagricultural sector. As mentioned above, although the model does not replicate the current magnitude of international trade in China, it is able to replicate the trend towards increased trade flows during the period considered in the simulation.

Table 2: Model results[16]

		Baseline calibration	
	Data	Closed economy	Open economy
$n_{a,1980}$	0.69	0.69	0.69
$n_{a,2005}$	0.45	0.15	0.46
TB_{2005}	0.69	–	0.36
gy	0.09	0.07	0.09
gy_a	0.07	0.03	0.07
gy_m	0.11	0.10	0.11
gk	0.10	0.09	0.12

[16] TB is total trade as a percentage of GDP, n_a is the employment share in agriculture, gy is the output growth, and gk is the growth rate of capital stock.

3.6 Counterfactual

In this section, we conduct simulations with our calibrated economy to estimate the agricultural sector's contribution and the contribution from trade to the recent performance of the Chinese economy. As noted above, the growth trajectory of the Chinese economy in the case of the open economy model is closer to that observed in the data than in the case of the closed economy. Thus, the first question that arises is what is the contribution of trade to China's development process. The figures below compare the path of the observed output with the trajectories of product in the open and closed economy cases. The open economy model explains 100% of the output trajectory of the Chinese economy while the closed economy explains only 74%. Because the models differ only by the insertion of the Chinese economy in international trade, this result suggests that international trade explains 26% of the path of the product of the Chinese economy in the period.

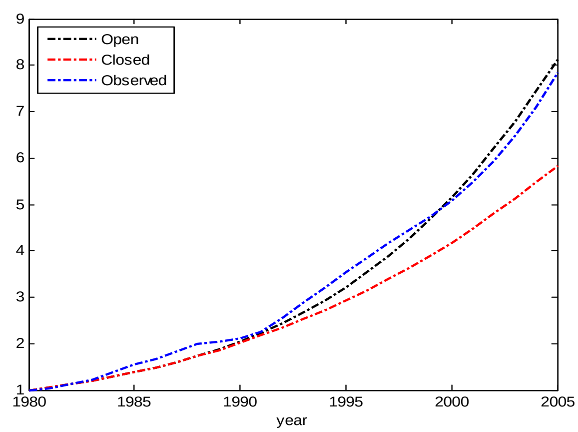


Figure 11: Output path in the Chinese economy

To calculate the contribution of the agricultural sector for the development of Chinese economy, we simulate our model for the case in which TFP growth in the agricultural sector is equal to zero and for the case in which

TFP in the nonagricultural sector is equal to 6.2%, the TFP growth in the agricultural sector. The simulations reflect the most extreme cases for the paths of TFP in each sector. In the first case, the TFP in agriculture remains stagnant and, in the second, the growth rate of TFP in the nonagricultural sector is the same as in the agricultural sector and therefore much higher than what was observed in the data.

As seen from the figures below, the results of the first experiment demonstrate that the share of workers in agriculture would have declined much more rapidly than observed in the data. One should also note that in the initial periods of the simulation, the share of workers in agriculture is higher than that in our baseline scenario. This follows from the fact that in the early periods of our simulations, the economy remains closed, which implies a slower reallocation of workers across sectors in scenarios in which the TFP growth rate in agriculture is lower.

Despite the lower TFP growth in the agricultural sector relative to the baseline scenario, the share of workers reallocated from agriculture to the nonagricultural sector is much higher, increasing the share of workers employed in the sector with the highest labor productivity. Thus, the lower productivity growth in the agricultural sector is partially offset by the productivity gains achieved by the transfer of labor to the sector with higher labor productivity. This means that although the aggregate output of the economy grows at a lower rate than that observed in the baseline scenario, it continues to exhibit a strong growth path throughout the period.

Note that this result differs from what would occur in the case of a closed economy, as the low TFP growth in the agricultural sector would cause significant part of the workforce to remain in the low productivity sector, and therefore there would be no compensation for the reallocation of labor from agriculture to the nonfarm sector. This difference between the closed and open economy results can be observed from the difference in the paths of relative output (relative to baseline) in the Chinese economy in the right-hand

figure below. In the case of an open economy, the more rapid reallocation of labor from agriculture to the nonagricultural sector would result in a decline in production lower than that observed in the case with a closed economy.

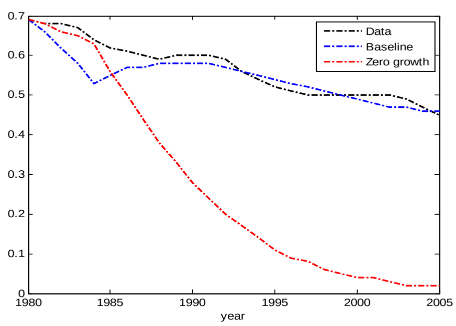


Figure 12: Employment share in Agriculture

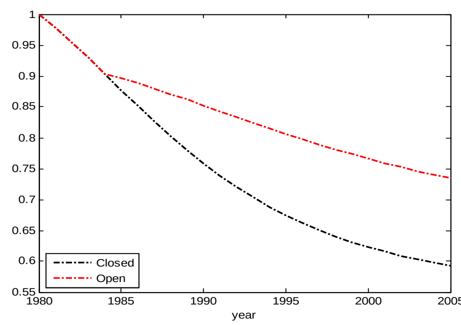


Figure 13: Relative output (in relation to basecase)

As expected due to the structure of the external sector in the model, low productivity growth in agriculture would cause the Chinese economy to specialize in producing the nonagricultural good that possesses the greatest comparative advantage. Thus, the model would predict that the Chinese economy would exhibit a large trade surplus in the nonagricultural sector and a large trade deficit in the farm sector. This mechanism, which is not present in the closed economy, would further increase the aggregate output of the economy, partially offsetting lower output growth in agriculture.

When we set TFP growth in the agricultural sector equal to zero, Chinese production in 2005 would have been 73% of that predicted by the baseline scenario for the open economy. In the case of the closed economy, maintaining a larger share of workers in the agricultural sector would contribute to a substantially reduced total output growth. In this case, the experimental results indicate that total output would be just 59% of the baseline closed economy. Therefore, the open economy model suggests that, despite that

the strong growth of TFP in agriculture was an important determinant of the growth path of the Chinese economy during the reform period, other factors such as rapid capital accumulation and strong growth in international trade also played an important role. Therefore, the exercise shows that the agricultural sector explained 27% of the path of the output of the Chinese economy in the open economy model.

In the second counterfactual, in which we consider the growth rate of TFP in the non-agricultural sector similar to the growth rate of TFP in the agricultural sector, the dynamic of labor reallocation across sectors in the closed economy is similar to the one exhibited by the open economy. In both cases, the decline in the share of workers in agriculture occurs very quickly. In the case of the open economy that reduction stems from the fact that an increase in income spurred by strong growth in TFP in each sector reduces the relative demand for the agricultural good, leading to a rapid decline of its price and therefore a transfer of labor from the agriculture to the nonagricultural sector. In the open economy, the mechanism is similar to that seen in the previous counterfactual, in which the economy specializes in the sector with higher labor productivity.

The results of this experiment are shown in the figures below. The reduction in the share of employed in agriculture occurs more rapidly in the open economy, which implies a higher output growth in this case. Considering the ratio between the output in the closed and in the open economy predicted by both counterfactuals, this measure decreases in both cases, which points to an underestimation of the output in the closed economy.

In the first counterfactual, in which we consider a zero growth rate for TFP in the agricultural sector, the final product in the closed economy is 58% of the output of the open economy. In the counterfactual in which TFP in the nonagricultural sector grows at the same rate that in the agricultural sector, the output in the closed economy is 93% of the GDP in the open economy.

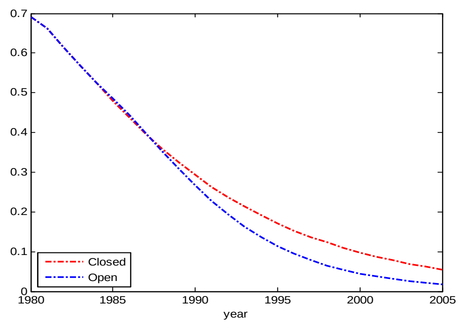


Figure 14: Employment share in agriculture - equal TFP growth rates

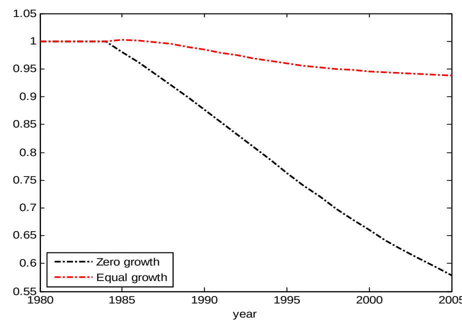


Figure 15: Relative output between closed and open economies

3.7 Conclusion

Our paper reviewed the recent experience of the Chinese economy from the perspective of a model of structural transformation and trade liberalization. As highlighted in previous sections, the observation that the relative price between agricultural and nonagricultural goods remained relatively stable during China's reform period implies that the predictions of a theoretical model of structural transformation using a closed economy to determine the relative price of the agricultural good is not compatible with the observed data.

In this sense, a closed economy model would tend to estimate a reallocation of workers from agriculture to the nonagricultural sector that is more rapid than observed in the data. By considering an open economy framework, our model is able to more accurately replicate the trend in the share of workers in each sector of the Chinese economy for the period from 1980 to 2005.

The first conclusion of our article is that international trade explained 26% of the path of per capita GDP in China in the post-reform period. This

result stems from the fact that the open economy model explains 100% of the growth path in China while the closed economy model explains only 74% of this trajectory.

Another important source of growth was the significant growth of total factor productivity in the agricultural sector. The counterfactual exercise using our calibrated model demonstrated that even if we assume 0.0% TFP growth in the agricultural sector, output in China would have been 73% of that observed in the period considered, which points to a contribution of 27% of the agricultural sector for Chinese economic development. This is because, in our model, this scenario of zero TFP growth in the agricultural sector would imply a greater reallocation of labor to the nonagricultural sector, a result that is the opposite of what would occur in a closed economy model. This shift occurs because, in an open economy framework, where the central planner selects the share of workers in each sector of the economy to maximize total output, the share of workers in the more inefficient sector would decline more rapidly. Other factors such as rapid capital accumulation also played an important role in explaining the strong growth of the Chinese economy.

In this sense, a framework that incorporates international trade reveals an additional important force behind the impressive growth of the Chinese economy in this period, which is not captured by traditional models that consider a closed economy framework.

4 Education convergence and growth divergence in Africa

4.1 Introduction

Most countries around the world experienced, in the recent decades, a significant increase in educational attainment. Both in developed and in emerging

economies, individuals choose to spend more time studying, regardless the economic situation of these countries. Even in economies with stagnant output per capita there was an increase in levels of education over the last thirty or forty years.

This widespread increase in schooling has been accompanied by a reduction in the dispersion of levels of education across countries of the world, although the gap between the levels of education, when we compare emerging economies with developed economies, is still considerable. Considering a sample of 84 countries, Restuccia and Vandenbroucke (2013 (c)) observed that the ratio between the educational attainment of the richest economies and the educational level of the poorer economies decreased from 6 times to 2 times between 1950 and 2005. That is, while a representative individual from the sample of rich countries was, on average, 6 times more educated than an individual in the sample of poor countries in 1950, fifty five years later this ratio fell to only 2.

This pattern is present even when considering economies as poor as those in sub-Saharan Africa. Although education levels in these countries are much lower than those observed in more developed economies such as the U.S. for example, the African economies accumulated education in a faster pace than that seen in the U.S. over the past decades. This reduction in the gap of educational attainment occurred despite the increase in the gap of per capita income in these countries when compared to the United States.

In this sense, our paper studies the evolution of human capital accumulation in African economies and seeks to explain the reasons for the faster increase in the levels of education in these economies when compared to high income economies. We will stress different mechanisms that potentially may explain the acceleration of schooling in the region such as: (i) the increase in life expectancy in most countries; (ii) technological gains that increased labor productivity; and (iii) the decline in the costs of education.

The relationship between education and economic development has been

explored in both directions of causality. Higher levels of education increase the labor productivity of the economy while high returns to education lead to an increase in the amount of education chosen by individuals. The literature that explores the former direction of causality is not conclusive about the impact of high schooling levels on the output growth of an economy. While some articles as Barro (2001) found evidence that education has a significant impact on economic growth, other papers such as Bills and Klenow (2000) concluded that educational attainment is barely able to explain one third of economic growth.

There is a literature that studies the process of human capital accumulation focusing on the relationship between life expectancy and education. This association stems from the observation that life expectancy has increased significantly in most countries over the past few years, a movement that has been explained by the adoption of better technologies in the health sector and the spread of disease-fighting techniques around the world. The increase in life expectancy can potentially contribute to the rise of the educational attainment because it affects the return of human capital investiment over the life cycle and, consequently, the choice of how much individuals want to educate themselves.

This relationship between life expectancy and education, as pointed out in Hazan (2009), stems from the fact that "The life expectancy at age 5 of American men born in the mid-19th century was 52.5 years and the average years of schooling were less than 9. Their peers, born a hundred years later, gained more than 16 years of life and invested 6 more years in schooling". Among the articles in the literature that explores the relationship between life expectancy and education, Soares (2005) finds that reductions in mortality (or gains in life expectancy at birth) are followed by reductions in fertility and increases in the rate of human capital accumulation. In this model, as well as in Enrlich and Lui (1991) Khakemi-Ozacan, Ryder and Weil (2000) and Boucekkine, de la Croix and Licandro (2002) longer lives become by

definition longer career span as there is not retirement. Ferreira and Pessôa (2007) also explore the relationship between longevity and education in a model calibrated to the U.S., but adds labor choice to the model. In this sense, education decision is influenced by the extensive margin - for how many years people work - but also by the intensive margin - how many hours a day people work[17].

There are, of course, many other factors affecting the recent increase in education levels explored in the literature. For our purposes, we highlight Restuccia and Vandenbroucke (2013 (a), 2013 (b) and 2013 (c)). In Restuccia and Vandenbroucke (2013 (c)), the authors study the convergence of educational attainment over time for a sample of countries. Their results emphasize the importance of productivity (and life expectancy) in explaining the bulk of differences in educational attainment across countries and their evolution over time. In Restuccia and Vandenbroucke (2013 (b)), they found that changes in the returns to education generate a substantial increase in educational attainment. They also found that the substantial changes in life expectancy explain a small portion of the change in educational attainment.

Our article adds to this literature by considering the impact of the reduction in education costs on the individual decision on how much education to acquire. We consider a implicit measure of the costs of human capital accumulation and test how changes in this variable affect individuals' decisions. Intuitively these costs changed a lot in the period across developing countries. In Brazil, for instance, fifty years ago there were few schools in the countryside, especially in small towns, for children older than 14 or 15 years old and no transportation for those living distant from the school. In contrast, there are now secondary schools even in the very small villages and free transportation for all kids that need it. All books and school material in public schools are now free. Clearly, the cost to send a kid to school decreased

[17]Hazan (2009), however, could not find any link between longevity and schooling, as opposed to Soares (2005).

significantly.

Note also that in the last decades many poor countries experienced strong migration of people from rural areas to the cities and consequently a fast process of urbanization. The supply of educational services and transportation tends to be lower in rural areas compared to urban areas, and distances to school are longer in rural areas. Hence, the costs for a kid to attend school are higher in the countryside, so that the reallocation of families to urban areas tends to contribute to the decline in the cost of education. Given the higher rural population in poor countries, the impact of the shift of labor to the cities on educational costs tends to be greater in less developed economies.

We develop a recursive model to investigate the impact of the cost of education, life expectancy and productivity on the individuals' education decision. Our goal is to quantify the role of each factor to the increase in educational attainment in some African economies throughout the period from 1970-2008 . In our model, in the first period of their lives individuals just receive an education investment which is chosen by their parents. The level of education chosen by an individual for his children depends on, among other variables, life expectancy, which is measured by a survival probability, and the cost of schooling. All individuals face a probability of death in the third period of their life.

The model is calibrated and simulated for five African economies that showed a significant increase in educational attainment in the last decades. The cost of education is measured using equilibrium conditions of the model and data. In essence this parameter is calibrated by making the model match the observed change in education during this period. We then use the calibrated model to perform some counterfactual exercises. When we keep the implicit cost of education constant at the 1970 level (but changing everything else to the 2008 values), we find, for instance, that schooling in Botswana would increase from 1.32 years to just 3.21 years, instead of the 8.82 observed

in the data. Similar results are obtained for all economies.

In addition to this introduction, the paper is organized as follows: in section 2, we present some key stylized facts concerning education attainment in Africa. In section 3, we present our recursive model, while in section 4 we present the recursive equilibrium of the model. The parameters of the model are calibrated in Section 5. In Section 6, we present some quantitative exercises in order to quantify the contribution of each factor to the increase in educational attainment. In section 7, we run some counterfactual simulations. Section 8 concludes the paper.

4.2 Stylized facts

Using the Barro and Lee database[18], World Development Indicators (WDI)[19] and Maddison database[20], we study the dynamics of the life expectancy, educational attainment, income per capita, spending on education and population mobility for a set of 31 African economies in the period from 1950-2010[21]. In this section, we summarize the main facts observed on these variables.

African countries are still far behind the developed economies when we look at the level of per capita income in these economies. When we compare the level of GDP per capita in African economies in relation to the U.S., we found that this measure, for most African economies, is below the levels observed for the U.S. economy in periods as distant as 1800. For example, only 14 countries (45%) out of our sample of 31 African economies had a level of per capita GDP in 2008 higher than the level of the U.S. economy in 1820.

Besides the low level of GDP per capita in most African economies, there

[18]Barro, Robert and Jong-Wha Lee, "A New Data Set of Educational Attainment in the World, 1950-2010." forthcoming, Journal of Development Economics.

[19]World Development Indicators, The World Bank.

[20]Bolt, J. and J. L. van Zanden (2013). The First Update of the Maddison Project; Re-Estimating Growth Before 1820. Maddison Project Working Paper 4.

[21]The choice of the period and number of countries is limited by the data availability.

was no convergence of this measure over the past few years. Only four out of thirty-one African economies in our sample have narrowed the gap in relative income (ratio of GDP per capita between African countries and U.S.) from 1950 to 2008 (Botswana, Mauritius, Swaziland and Lesotho). In some cases (e.g., Central African Republic, Liberia and Niger) GDP per capita in 2008 was lower than the level observed in 1950.

On the other hand, the number of years of education in all African economies grew faster than in the U.S. economy in the period considered. In the case of Mali, for example, the ratio of educational attainment between the United States and this country dropped from 56.1 in 1950 to 5.5 in 2010. For the four African economies that exhibited a convergence in the measure of per capita income, the gap of educational attainment in relation to the United States between 1950 and 2010 decreased substantially: (i) From 6.8 to 1.4 in Botswana, (ii) from 3.4 to 2.0 in Lesotho; (iii) from 3.4 to 1.7 in Mauritius, and (iv) from 6.9 to 1.7 in Swaziland.

Even when we consider the level of education in an intermediate age group, to control for possible changes in the demographic structure of a country, the ratio of educational attainment between the United States and African countries declined for all the 31 cases considered. Hence, the period from 1950 to 2010 exhibited a faster increase in educational levels in African economies than in the U.S. economy. On the other hand, we saw a contraction in relative GDP per capita in most of African countries, with only four countries showing an increase of this measure within the period considered. The figure below confirms this finding by showing a weak or nonexistent relationship between change in the level of education and change in relative income per capita from 1950 to 2010.

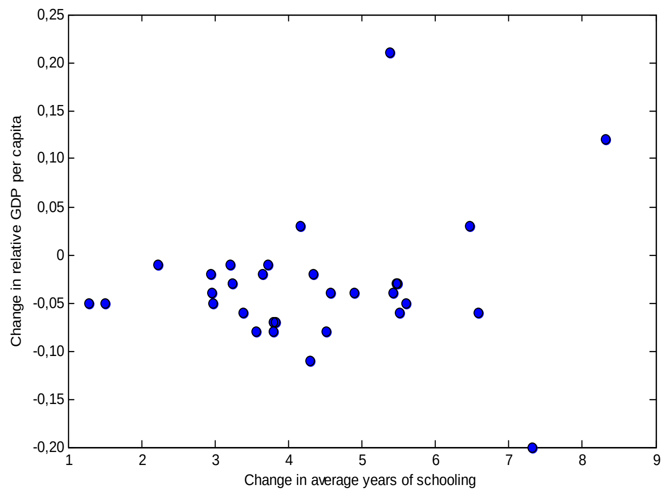


Figure 1: Relative income versus education in African countries

These facts are consistent with the observations outlined in the introduction that: (i) increased levels of education is a widespread phenomenon, common to all economies of the world, (ii) the gap in educational attainment in poor and rich economies have narrowed over the past decades, and (iii) this convergence in education levels was not accompanied by a convergence of per capita income. In the table below we summarize these facts for our sample of African economies[22]. All countries exhibited a drop in the ratio of educational attainment (ratio of average years of schooling in US to the average years of schooling in the selected economy) while only a few of them exhibited an increase in relative GDP per capita.

[22] We considered the twenty economies with the highest per capita income in 2010.

Table1: Per capita GDP and schooling in Africa

	Schooling ratio[23]		Relative GDP per capita[24]	
	1950	2010	1950	2010
Mauritius	3.4	1.7	0.26	0.47
South Africa	2.0	1.5	0.27	0.15
Botswana	6.8	1.4	0.04	0.15
Namibia	3.5	2.1	0.23	0.15
Gabon	9.9	1.6	0.33	0.12
Swaziland	6.9	1.7	0.08	0.10
Mozambique	15.9	7.2	0.12	0.07
Congo	10.6	2.1	0.13	0.07
Lesotho	3.4	2.0	0.04	0.06
Ghana	12.4	1.8	0.12	0.05
Sudan	24.7	4.0	0.09	0.05
Senegal	5.1	2.5	0.13	0.05
Benin	15.9	3.0	0.11	0.04
Mauritania	6.5	2.9	0.05	0.04
Cameroon	11.5	2.1	0.07	0.04
Mali	56.1	5.5	0.05	0.04
Kenya	7.1	2.0	0.07	0.04
Cote dIvoire	10.5	2.8	0.11	0.04
Gambia	24.7	3.7	0.06	0.03
Rwanda	27.1	3.3	0.06	0.03

Using the WDI database, we analyze the behavior of the variable education spending as percentage of Gross National Income (GNI) in African countries in the 1970-2010 period. Overall, there was an increase in edu-

[23]Ratio between educational attainment in U.S. and the level of education in the African country.

[24]Ratio between GDP per capita in the selected county and GDP per capita in US.

cation spending in Africa over the past decades. Considering our sample of 31 countries, there was an increase in education spending in 70% of our sample over the period considered. The countries that had the largest increase in education spending in the period were (Figure 2): Lesotho (from 2.8% to 9.7%), Burundi (from 2.2% to 8.7%), Botswana (from 4.0% to 7.6%), Swaziland (from 3.0% to 6.9%) and Togo (from 2.0% to 4.4%).

On average for the sample considered, spending on education as a proportion of total income increased from 3.2% to 4.2% in the period. Some countries, however, presented a decline on education spending. They are: Congo, from 5.7% to 2.5%, Central African Republic, from 4.2% to 1.1%, Zambia, from 3.6% to 1.3%; Sudan, from 3.5% to 0.9%; and Côte d'Ivoire, from 5.4% to 4.3%.

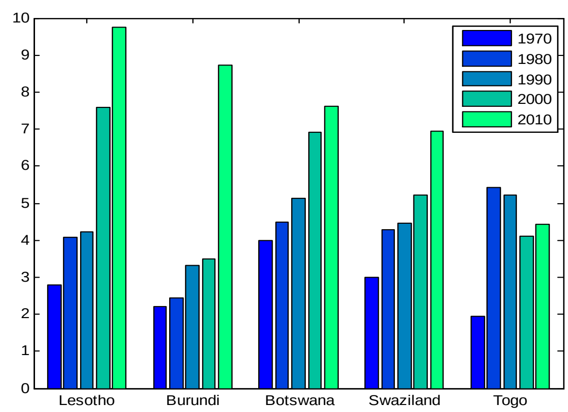


Figure 2: Current expenditures on education (% of GNI)

A good proxy to measure the dynamics of education costs in the last decades is the percentage of people in rural areas. As noted in the introduction, countries with a high percentage of the population in rural areas tend to have higher educational costs, since the cost of education in rural areas

tends to be higher than in urban areas, which usually are characterized by better infrastructure, greater access to books, greater supply of schools, etc. Thus, the migration of people from countryside to cities tends to contribute to the reduction of the education costs of a country.

African countries undergo a process of population mobility throughout the period, since most of them still had a high proportion of the population in rural areas. In the average of the thirty-one African economies, this measure decreased from 86.5% in 1960 to 69.4% in 2010 (change of 26.1 percentage points). In the United States, the share of population in rural areas dereased from 30.0% in 1960 to 17.4% in 2010 (12.6 percentage points). As African countries still have a high percentage of people in rural areas compared to the developed economies, this factor tends to contribute to a further reduction in the cost of education in the coming years.

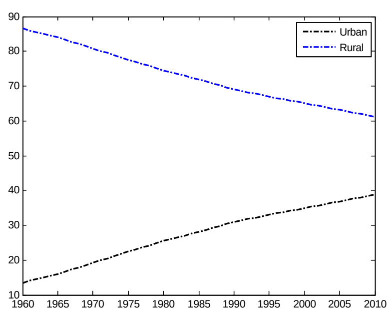


Figure 3: Rural and Urban population - Africa

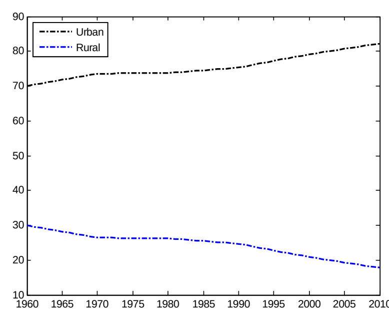


Figure 4: Rural and urban population - USA

Life expectancy at birth in the United States increased by 8.9 years between 1960 and 2011, from 69.8 years to 78.6 years in 2011. The average life expectancy in African countries increased by 13.4 years over the same period (from 42.1 years to 55.5 years). Thus, African countries were able to reduce the difference in life expectancy in relation to the U.S. economy throughout the period. The data also indicate that the gain in life expectancy over the

U.S. was widespread across African countries, with 77.4% of the countries exhibiting a bigger increase in life expectancy than the one observed in the U.S. The biggest increase in life expectancy occurred in Gambia (24.9 years), while the smallest increase was in Zimbabwe, where life expectancy remained relatively stable during the period (Figure 5).On average for the sample considered, spending on education as a proportion of total income increased from 3.2% to 4.2% in the period. Some countries, however, presented a decline on education spending. They are: Congo, from 5.7% to 2.5%, Central African Republic, from 4.2% to 1.1%, Zambia, from 3.6% to 1.3%; Sudan, from 3.5% to 0.9%; and Côte d'Ivoire, from 5.4% to 4.3%.

Much of the increase in life expectancy in African countries occurred between 1950 and 1990, before the period marked by the dissemination of HIV/AIDS. For example, when we consider the ratio of life expectancy in the United States and life expectancy in the African countries, one can see a strong reversal in this measure from the end of 1980s to 2000. In the more recent period, life expectancy in African countries has increased faster than in United States (Figure 6).

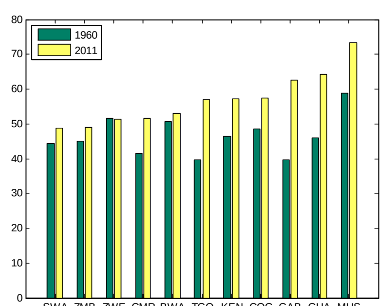


Figure 5: Life expectancy in selected African countries

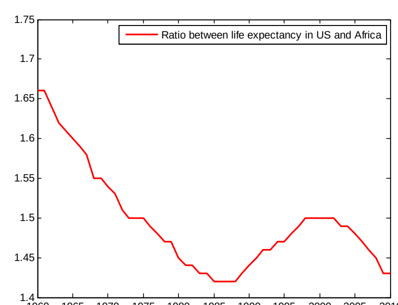


Figure 6: Relative life expectancy in African countries

Thus, the observed facts on African economies show that: (i) there has been a process of divergence of per capita income in most economies, with

only four of them exhibiting a relative per capita income in 2010 higher than that observed in 1950; (ii) there has been a spread out increase in education levels in Africa and this increase in educational attainment has been faster than that observed in the U.S.; (iii) spending on education measured as a percentage of GNI increased in recent years; (iv) there has been a strong mobility of the population from rural to urban areas, suggesting a decline in education costs in Africa; and (v) the increase in life expectancy between 1960 and 2011 was higher than in the U.S. economy, with this movement being less pronounced in the most recent period.

4.3 Model

4.3.1 Demography

The economy is inhabited by multiple cohorts of individuals of different ages. Each cohort is comprised of a continuum of measure one of individuals who live for three periods. In the first period, individuals only study and do not take any economic decision. The educational attainment of an individual is determined in the first period and individuals receive an educational investment which is chosen by their parents. At the end of the second period, individuals leave home and constitute their own household. In this period, individuals work, consume, accumulate capital and choose the educational attainment of their children. In the third period, individuals only work and consume.

Life span is uncertain and this is captured by the fact that all individuals face a probability of death in the third period of their life. Hence, each individual is alive in the second period with probability $\psi_2 = 1$ and is alive in the third period with probability $\psi_3 < 1$.

We can directly map the survival probability into the time invariant age profile of the population denoted $\{\mu_t\}_{t=2}^{3}$, by assuming that the fraction of

agents in cohort t in the population is given by:

$$\mu_2 = \frac{1}{1+\psi_3}, \tag{17}$$

$$\mu_3 = \frac{\psi_3}{1+\psi_3}. \tag{18}$$

4.3.2 Households

Preferences: Temporary utility is given by:

$$U(c_t) = \frac{c_t^{1-\gamma}}{1-\gamma}. \tag{19}$$

where γ is the risk aversion parameter.

Labor supply: In the first period, individuals only study. During the periods in which he is working (i.e, second and third periods) an individual supplies to the market a total of $h_t e^{z_t}$ efficiency units which are paid at a rate w, where $z \sim N(-\frac{\sigma_z^2}{2}, \sigma_z^2)$ is a temporary shock in the individual's earnings and h_t is human capital.

Labor productivity shocks are independent across agents. As a consequence, there is no uncertainty regarding the aggregate labor endowment even though there is uncertainty at the individual level.

Human capital accumulation: The law of motion for human capital can be written as follows:

$$h_{t+1} = e^{u_t}\left[1 + f(s_t)\right] h_t^{\varphi}, \tag{20}$$

where h_t is the human capital, and u_t evolves stochastically according to an AR(1) process, $u_t = \rho u_{t-1} + \varepsilon_t$, with innovations $\varepsilon_t \sim N(-\frac{\sigma_\varepsilon^2}{2}, \sigma_\varepsilon^2)$. The latter term can be understood as the ability of the individual at birth, which is permanent and is correlated to the ability of parents. The parameter φ can be understood as the influence of parents human capital. Moreover, the

returns to schooling is defined as $f(s_t) = \frac{\theta}{1-\phi} s_t^{1-\phi}$, following the specification in Bills and Klenow (2000). We also requires that $\phi > 0$ due to the evidence of diminishing Mincerian returns to schooling.

Asset accumulation: Individuals trade a risk free asset which holdings we denoted by a_t. Asset holdings are subject to an exogenous lower bound. More precisely, we follow Conesa et al (2009) in assuming that agents are not allowed to contract debt at any age, so that the amount of assets carried over from age t to $t+1$ is such that $a_{t+1} \geq 0$. Because no agent can hold a negative position in assets at any time, we assume without loss that assets take the form of capital, as in Aiyagari (1994).

Budget constraint: Gross earnings received in the second and third periods are taxed at a flat rate $\tau_{w,t}$. Individuals face budget constraint in the second and third periods.

In the second period, when individuals constitute a household, the flow budget constraint that individuals face in our model is as follows:

$$c_t^2 = (1 - \tau_{w,t})\, w_t h_t e^z - \tau_s s_t - a_{t+1} + \epsilon \tag{21}$$

The term $w_t h_t e^z$ is the income of an individual, $\tau_{w,t}$ is a tax on income and the term $\tau_s s_t$ is the cost of schooling, represented by the rate τ_s and the amount of schooling choosen by the parents for their children. ϵ is a lump sum transfer related to the involuntary bequests left by those who die before reaching the third period. Note that the higher the rate τ_s, the lower the level of education chosen by parents for their children. That is, the costs of education enter in the budget constraint of the individual in the second period of their life cycle, when he has to choose the level of education of their offspring.

In the third period, the budget constraint is as follows:

$$c_t^3 = (1 + r)\, a_t + (1 - \tau_{w,t})\, whe^z \tag{22}$$

By assumption $a_1 = 0$. Moreover, given that there is no altruistic bequest motive and death is certain at the end of the third period, agents who survive until the third period consume all their available resources, that is, $a_4 = 0$.

4.3.3 Technology

The technology for producing the consumption good is summarized by a Cobb-Douglass production function with constant returns to scale:

$$Y = K^{\alpha} (BN)^{1-\alpha}, \tag{23}$$

where $B = H^{\xi} A^{1-\xi}$ is the productivity of the economy, K is aggregate capital and N is aggregate efficient units of labor. The productivity can be broken down into two components: human capital acumulation H and a scale parameter A representing the total factor productivity (TFP) of the economy. ξ is the share of human capital in B.

The standing representative firm solves every period the static optimization problem:

$$\max_{K,N} \left\{ K^{\alpha} \left(H^{\xi} A^{1-\xi} N \right)^{1-\alpha} - \delta K - wN - rK \right\} \tag{24}$$

where r is the rental rate of capital and w is the wage. Note that we assume that the rental rate is net of depreciation costs which are incurred directly by the firm.

The first order conditions for the firm's profit maximization problem are,

$$(1-\alpha) H^{\xi} A^{1-\xi} K^{\alpha} N^{1-\alpha} = w \tag{25}$$

and

$$\alpha H^{\xi} A^{1-\xi} K^{\alpha-1} N^{-\alpha} - \delta = r. \tag{26}$$

4.3.4 Government

The government levies taxes on labor income, at a linear and potentially age-dependent rate, $\tau_{w,t}$. Tax revenues are raised to finance an exogenous flow of expenditures, G. As previously discussed we also assume that the government collects the accidental bequests and transfers it to all agents in the economy on a lump-sum basis. The Government budget constraint is, therefore,

$$G \leqslant \sum_t \tau_{w,t} y_t - \epsilon. \tag{27}$$

The term y_t is the income of an individual.

4.4 Recursive equilibrium

Let $V_2(\omega)$ denote the value function of an individual in the second period, where $\omega = (a, u, z)$ is the individual state space. Thus, the optimization problem of individuals in the second period can be recursively represented as follows:

$$V_2\left(u, h, z\right) = \max_{s, a' \geqslant 0} u(c_2) + \beta\left[\psi_3 E_{z'} u(c_3) + E_{u',z'} V_2\left(u', h', z'\right)\right] \tag{28}$$

subject to:

$$c_2 = \left(1 - \tau_w\right) whe^z - \tau_s s - a' + \epsilon,$$

$$h' = e^u \left[1 + f\left(s\right)\right] h^{\varphi},$$

$$c_3 = \left(1 + r\right) a' + \left(1 - \tau_w\right) whe^z$$

Note that in the optimization problem, the individual cares about his children's human capital. In the third period, agents consume all of their resources as we are not considering bequests in our model.

A recursive competitive equilibrium for the economy with human capital accumulation is as follows.

Definition 3 *Given the policy parameters, a recursive competitive equilibrium for the economy is a value function $V_2(\omega)$, policy functions for individual asset holdings $d_{a,t}(\omega)$, for consumption $d_{c,t}(\omega)$, for the children's schooling acquisition $d_{s,t}(\omega)$, prices $\{w, r\}$, age dependent but time-invariant measures of agents $\lambda_t(\omega)$, transfers ϵ and a tax on labor income τ_w such that:*

1. $\{d_{a,t}(\omega), d_{c,t}(\omega), d_{s,t}(\omega)\}$ *solve the dynamic problems in* (28).

2. *The individual and aggregate behaviors are consistent, that is:*

$$K = \sum_{t=1}^{T} \mu_t \int d_{a,t}(\omega)\, d\lambda_t,$$

$$N = \sum_{t=1}^{T} \mu_t \int \left[1 + f(s_t(\omega))\right] h^{\varphi} \exp(u + z_t)\, d\lambda_t.$$

3. $\{w, r\}$ *are such that they satisfy the optimum conditions* (25) *and* (26).

4. *The final good market clears:*

$$\sum_{t=1}^{T} \mu_t \int_{\Omega} \left\{d_{c,t}(\omega) + \left[d_{a,t} - (1-\delta)\, d_{a,t-1}(\omega)\right]\right\} d\lambda_t = K^{\alpha} \left(N H^{\xi} A^{1-\xi}\right)^{1-\alpha}.$$

5. *The measure of agents in equilibrium is obtained by iterating on the distribution until it converges to the invariant distribution.*

6. *The distribution of accidental bequests is given by:*

$$\epsilon = \mu_2 \int_{\Omega} (1 - \psi_3)\, d_{a,t}(\omega)\, d\lambda_t.$$

7. Taxes are such that the government´s budget constraint,

$$G = \sum_{t=1}^{T} \mu_t \int_{\Omega} \tau_{w,t} w f \left(d_{s,t}\left(\omega\right)\right) \exp\left(u_t + z_t\right) d\lambda_t.$$

is satisfied every period.

4.5 Calibration

We have selected five African economies (Botswana, Lesotho, Niger, Gambia and Mauritius) to calibrate our model. The countries were selected by the availability of data and by the fact that Botswana, Lesotho and Mauritius were the countries that exhibited convergence of per capita income (i.e., GDP per capita relative to the U.S. in 2010 was higher than the relative per capita GDP in 1970) while Gambia and Niger were the countries with the greatest gap in terms of education levels in comparison to the United States. The values for the parameters that are equal for all the African economies are summarized in table 2. The calibration strategy was as follows:

The survival probability was estimated in order to satisfy (17) above. In this case, we considered the population distribution profile for each of the African countries and equation (17) to calculate the survival probability in the third period of the model.

In order to calibrate the preference parameters we proceed as follows. First, we choose the discount factor β in such a way that the equilibrium of our benchmark economies implies a capital-output ratio equal to the ratio observed in the data in 1970 for each of the African countries. Then we fix the parameter γ to 2.0, which is consistent with the empirical evidence in Mehra and Prescott (1985).

For the parameters θ and ϕ in the returns to education function, we selected the values of 0.32 and 0.58 as estimated in Bills and Klenow (2000). For the parameter φ, that measures the sensitiveness of an individual's hu-

man capital to human capital of the individual's parents, we selected a value of 0.10, inside the range from 0 to 0.19 estimated by Bills and Klenow (2000).

The parameters that characterized the stochastic component of individuals productivity are $(\sigma_u^2, \sigma_z^2, \sigma_\epsilon^2)$. Several authors have estimated similar stochastic process for labor productivity. Controlling for the presence of measurement errors and/or effects of some observable characteristics such as education and age, the literature provides a range of $[0.10, 0.25]$ for σ_ϵ^2. In this article, we rely on the estimates of Kaplan (2012), setting $\sigma_\epsilon^2 = 0.016$. For the variance of the permanent shock, σ_u^2, we choose 0.02 in line with the estimates as in Kaplan (2012)[25]. Moreover, the parameter ρ that measures the persistence of the ability of an individual at birth is given by 0.65 also in line with the estimates in Kaplan (2012).

Then, the parameter σ_z^2 was chosen in order to the Gini index for labor income in the model to match its counterpart in the data, which is 0.36. This is the Gini index for Niger in 1992. Due to lack of data availability for the Gini index for African economies in periods prior to 1990, we selected the first year of the WDI database with information available for this variable in the five African countries considered in our analysis. The value obtained for σ_z^2 is in line with the estimates in Erosa and Koreshkova (2007).

The values of technological parameters (α, δ) are also summarized in Table 2. We chose a value for α based on U.S. time series data from the National Income and Product Accounts (NIPA). The depreciation rate, in turn, is obtained by $\delta = \frac{I/Y}{K/Y} - g$. We set the investment-product ratio I/Y equal to 0.25 and the capitalproduct ratio K/Y equal to 3.0. The economic growth rate, g, is constant and consistent with the average growth rate of GDP over the second half of the last century. Based on data from Penn-World Table, we set g equal to 2.7%, which yields a depreciation rate of 5.4%.

[25] The values are in annual terms. To compare with the values estimated in the literature we have to take into account that a period in our model represents 25 years.

Table 2: Parameters of the model

Parameter	Value	Source/Target
γ	2.00	Micro evidence
σ_z^2	0.02	Gini Index of 0.36
ρ	0.65	Kaplan (2012)
σ_u^2	0.10	Kaplan (2012)
σ_ϵ^2	0.016	Kaplan (2012)
ϕ	0.58	Bills and Klenow (2000)
θ	0.32	Bills and Klenow (2000)
φ	0.10	Bills and Klenow (2000)
δ	0.05	see text
α	0.36	NIPA

The value for B, that is a composite of the total factor productivity of the economy and human capital accumulation, is determined in such a way to satisfy (23). We can rewrite this equation as follows:

$$\frac{Y}{K} = \frac{K^{\alpha}(NB)^{1-\alpha}}{K} = \left(\frac{K}{NB}\right)^{-(1-\alpha)} = \left(\frac{K}{Y}\frac{Y}{NB}\right)^{-(1-\alpha)}$$

$$B = \left(\frac{Y}{K}\right)^{\frac{\alpha}{1-\alpha}}\left(\frac{Y}{N}\right) \tag{29}$$

Hence, the value for the variable B is determined in order to satisfy (29). The parameter ξ, which reflects how much of the productivity growth stems from the accumulation of human capital is given by 0.50, consistent with the empirical evidence as in Erosa and Koreshkova (2007). The table below shows the values for B in 1970 and 2008 in each of the African economies. Only Botswana and Mauritius exhibited an increase in productivity in 2008 compared to 1970:

Table 3: Change in B

	1970	2008
Botswana	0.98	1.42
Gambia	1.02	0.84
Lesotho	1.13	0.96
Mauritius	1.79	1.90
Niger	0.81	0.57

We specify the others parameters related to government activity. First, we set government consumption, G, to the share of government consumption (as % of GDP) observed in the data for each of the African economies under the baseline calibration. The labor income tax rate is determined in such a way that the government budget balances in equilibrium. The table 4 summarizes the values for G observed in the data for each economy.

Finally, the parameters τ_s and A are determined endogenously by the model. Namely, τ_s is calibrated so that the model reproduces the observed levels of schooling in the data, while A is calibrated so that the model reproduces a value for B consistent with the observed data, which is calculated from (29). Calibration is performed in 1970 and 2008.

Table 4: Observed data for selected variables in the five African countries

	Botswana		Gambia		Lesotho		Mauritius		Niger	
	1970	2008	1970	2008	1970	2008	1970	2008	1970	2008
G/Y	33%	12%	17%	11%	6%	22%	22%	11%	26%	18%
K/Y	2.06	2.84	1.16	2.29	1.24	5.13	1.08	3.25	4.38	4.75
$l.exp$	54.4	52.7	38.2	57.5	48.9	45.9	63.1	72.6	38.3	53.3
s	1.34	8.82	0.43	2.79	3.16	5.78	3.70	7.20	0.41	1.44

4.6 Simulation

In this section, we simulate our calibrated model. The exercises are conducted for the years 1970 and 2008 due to the unavailability of data for

education spending in years prior to 1970. The goal of this section is to explain the apparent contradiction observed for African economies between the divergence in income per capita and the convergence in education levels in relation to the U.S. economy. As noted in the previous sections, the following factors could have explained the increased levels of schooling in Africa: lower education costs, increased life expectancy and productivity gains in some cases (i.e., Botswana, Mauritius and Lesotho). Thus, we use the calibrated model above to quantify the contribution of each factor to the rising levels of education in Africa.

Interesting to note that, Botswana and Lesotho are countries which were characterized by strong spread of AIDS (as documented in Ferreira and Santos (2013)) and, consequently, by low increase in life expectancy over the past decades. Thus, considering the structure of our model, the relative increase of educational attainment in these countries over the last decades was probably explained by factors like the reduction of educational costs and the increase in productivity in the same period.

The table below summarizes the main results from our simulation. The first thing to note from our simulations is the spread out decrease in the cost of education across African economies. In Botswana, for example, the rate τ_s, which measures the cost of education, decreased from 0.23 in 1970 to 0.06 in 2008, what represented a reduction of 73% in education costs in the period. This reduction in the cost of education occurred at the same time that government consumption (as a percentage of GDP) declined significantly over the period. By the structure of our model, this reduction in government consumption has led to a reduction in income taxes, raising the income of individuals and contributing to the increase in education spending in the period.

Another important aspect to highlight is the change in productivity (A) estimated by the model in 2008 compared to 1970. Almost all the economies considered in our study presented a decline in productivity in 2008. Only

Botswana presented an increase in the productivity measure from 0.51 in 1970 to 0.54 in 2008 what suggest a minor role for the path of productivity in explaining the increase in educational attainment in African countries in the last decades.

Table 5: Model simulations: 1970 vs 2008

	Botswana		Gambia		Lesotho		Mauritius		Niger	
	1970	2008	1970	2008	1970	2008	1970	2008	1970	2008
Y/N	100	192	100	30.76	100	83.73	100	127.7	100	15.89
A	0.51	0.54	0.76	0.31	0.54	0.31	1.21	0.91	0.52	0.19
s	1.34	8.82	0.43	2.79	3.16	5.78	3.70	7.20	0.41	1.44
τ_s	0.23	0.06	0.35	0.26	0.17	0.12	0.15	0.08	0.36	0.31
τ_w	22%	14%	16%	13%	7%	15%	17%	9%	23%	17%

4.7 Countefactuals

As suggested by the simulation outlined above, the sharp decline in the costs of education tends to be an important driver of the increase in educational attainment in Africa between 1970 and 2008. To measure the contribution of this factor to the increase in schooling in African countries, we conducted a counterfactual exercise in which we maintain τ_s constant and equal to that estimated by the model in 1970 and simulate what would have been the schooling value observed in 2008 if the values of the other explanatory variables in the model (government consumption, TFP (A) and life expectancy) were equal to the simulated values for these variables in 2008. That is, the values of the explanatory variables were exactly the same as in the simulation results presented above for 2008 and we maintained the value of τ_s rate equal to the estimated value of this variable in 1970.

In this sense, the exercise simulates what would have been the level of education in African countries if the costs of education have not declined over the period. The results are summarized in the table below:

Table 6: Counterfactual: changing everything except τ_s

	Botswana		Gambia		Lesotho		Mauritius		Niger	
	1970	2008	1970	2008	1970	2008	1970	2008	1970	2008
$\frac{Y}{N}$	100	122	100	23.1	100	69.4	100	113.7	100	12.9
s	1.34	3.21	0.43	1.10	3.16	3.92	3.7	4.88	0.41	0.81
A	0.51	0.54	0.76	0.31	0.56	0.31	0.82	0.91	0.61	0.18
τ_s	0.23	0.23	0.35	0.35	0.17	0.17	0.15	0.15	0.36	0.36
τ_w	22%	17%	16%	14%	7%	20.3%	17%	10.8%	23%	18.4%

The results of the counterfactual indicate that the increase in levels of education in each African country would have been much lower than that observed in the simulation in which the value of τ_s is determined by the model in 2008. That is, if the cost of education remained constant at the level observed in 1970, African countries would have experienced a much smaller increase in the level of schooling. By construction, the model replicates 100% of the high levels of education between 1970 and 2008 in the baseline scenario, since the rate τ_s is calibrated in order to match the values of schooling projected by the model to those observed in the data.

Thus, the counterfactual suggests that the reduction in the cost of education explained the majority of the increase of the levels of education between 1970 and 2008 for the average of African countries considered in the simulation. Other factors (TFP and life expectancy) explain only a small part of the rise in educational attainment in African countries. The results do not vary much among African economies considered in the study. The largest contribution arising from the reduction in education costs occurred in Botswana while in the case of Niger, the contribution of the decrease in costs of education to the increase in schooling in the period was the smallest contribution among African economies considered.

In the second counterfactual, we are interested in calculating the contribution of the gains in life expectancy for the dynamics of education in

African countries. To do this, we kept the value of life expectancy in each African country equal to its value in 1970 and changed the values of the other explanatory variables in the model (government consumption, TFP and costs of education) to the values of these variables estimated in the base case simulation. Table 7 shows the results of the counterfactual.

Table 7: Counterfactual: changing everything except life expectancy

	Botswana		Gambia		Lesotho		Mauritius		Niger	
	1970	2008	1970	2008	1970	2008	1970	2008	1970	2008
$\frac{Y}{N}$	100	198	100	17.76	100	88.45	100	120.2	100	8.89
s	1.34	9.21	0.43	1.00	3.16	6.13	3.7	6.40	0.41	0.67
A	0.51	0.54	0.76	0.31	0.56	0.31	0.82	0.91	0.61	0.18
τ_s	0.23	0.06	0.35	0.26	0.17	0.12	0.15	0.08	0.36	0.31
τ_w	22%	13.7%	16%	13.3%	7%	14.7%	17%	9.2%	23%	17.7%

The most interesting cases are Botswana and Lesotho, countries that presented a decrease in life expectancy between 1970 and 2008. As can be seen from the results above, the level of education in Botswana would have increased from 1.34 years to 9.21 years in the counterfactual with life expectancy compared to 8.82 years observed in the data. In Lesotho, the educational attainment would have increased from 3.16 years to 6.13 years versus 5.78 years observed in the data. For the remaining cases, we highlight the contribution of the strong increase in life expectancy to the levels of education in Gambia. In this counterfactual in which we maintain the life expectancy equal to the level of 1970, the level of education in the country would increase from 0.43 year to 1.0 year, below the level of 2.79 years observed in the data.

In this sense, the contribution of the evolution of life expectancy to the dynamics of education in Africa was significant in some cases (e.g., Gambia), but was lower than the contribution of the reduction of educational costs

between 1970 and 2008. In countries that exhibited a slight decline in life expectancy in the period (Botswana and Lesotho), the decline in educational attainment due to the lower life expectancy was not significant. Therefore, the increase in life expectancy was an important factor in some cases and less important in others, reinforcing the conclusion of the previous counterfactual that most of the gains in education in Africa was due to the reduction of educational costs.

4.8 Conclusion

In this paper, we quantified the contribution of the main drivers of schooling to the increase in educational attainment in five selected African economies in the 1970-2008 period. Our paper is motivated by the fact that the increase in education levels observed in African countries between 1970 and 2008 was faster than in the United States and occurred concomitantly to a reduction in per capita output on these economies compared to the U.S. In only three African countries there was an increase in GDP per capita between 1970 and 2008 while the increase in schooling was greater than that observed in the U.S. in most of these countries. Moreover, one can also observe an increase in life expectancy at birth and a decline in education costs in these countries throughout the period.

Using a recursive general equilibrium model which takes into account the contribution of change in life expectancy, cost of education and produtivity to schooling we estimate that most of the increase in schooling in African countries was due to the sharp reduction in education costs observed in recent decades. The model estimates that 69% of the increase in educational levels in these countries was explained by the decrease in the costs of education in the period. The high contribution coming from the decline costs of education to the increase in schooling is observed in all the economies considered in the study.

References

[1] S Rao Aiyagari 1994, "Uninsured idiosyncratic risk and aggregate saving". *Quarterly Journal of Economics*, 109(3):659–684.

[2] Chong-En Bai, Chang-Tai Hsieh and Yingyi Qian (2006) "The Return to Capital in China," *Brookings Papers on Economic Activity*, Economic Studies Program, The Brookings Institution, vol. 37(2), pages 61-102.

[3] Barro, Robert J 1991, "Economic Growth in a Cross Section of Countries.", *Quarterly Journal of Economics*, 106(2), pp. 407-443.

[4] Bell, F. and Miller, M. 2005, "Life Tables for The United States Social Security Area 1900-2100," Actuarial Actuarial Study 120, Social Security Administration 2005.

[5] Bils, M. and P. J. Klenow 2000, "Does Schooling Cause Growth?", *American Economic Review*, 90(5), pp. 1160-1183.

[6] J. Birchenall and K. Cao (2013) "Agricultural Productivity, Structural Change and Economic Growth in Post-Reform China".

[7] Blyde, J. and E. Fernandez-Arias, (2006). "Why Does Latin America Grow More Slowly?" in Blyde, J., Férnandez-Arias, E. and R. Manuelli, eds., *Sources of Growth in Latin America: What is Missing?* Washington, DC: Inter-American Development Bank.

[8] Boucekkine, R; D. de la Croix and O. Licandro, 2002. "Vintage human capital, demographic trends and endogenous growth," *Journal of Economic Theory*, 104(2): 340-375.

[9] L. Brandt, Chang-tai Hsiesh, and X. Zhu (2008) "Growth and Structural Transformation in China".

[10] L. Brandt and X. Zhu (2010) "Accounting for China's Growth", *IZA, discussion paper series.*

[11] Chenery, H. and Syrquin M. (1975) Patterns of Development 1950-1970. Oxford, Oxford University Press.

[12] Cole, H. L., L. E. Ohanian, A. Riascos and J. A. Schmitz Jr., (2005). "Latin America in the Rearview Mirror". *Journal of Monetary Economics*, 52: 69-107.

[13] Conesa, Juan Carlos, Kitao, Sigiri and Krueger, Dirk 2009, "Taxing capital? not a bad idea after all", *American Economic Review*, 99(1):25–48, 2009.

[14] Costa, Carlos E. and Santos, M. 2012, "Age-dependent Taxation with Endogenous Life-cycle Path for Wages".

[15] Duarte, M. and Restuccia, D. (2005) "The Structural Transformation and Aggregate Productivity in Portugal," Portuguese Economic Journal, 6(1): pp.23-46.

[16] Duarte, M. and D. Restuccia, (2010), "The Role of the Structural Transformation in Aggregate Productivity" Quarterly Journal of Economics, 125, pp. 129-173.

[17] Echevarria, M. (1997) "Changes in Sectoral Composition Associated with Growth," International Economic Review, 38: pp. 431-452.

[18] Andrés Erosa and Tatyana Koreshkova 2003, "Progressive Taxation in a Dynastic Model of Human Capital", Journal of Monetary Economics, Volume 54 (3), pp. 667-685.

[19] Enrlich, I. and F. Lui, 1991. "Intergenerational Trade, Longevity, Intrafamily Transfers and Economic Growth," Journal of Political Economy, 99(5): 1029-1059.

[20] Ferreira, P., Pessôa, S. and F. Veloso, (2013) "On the Evolution of Total Factor Productivity in Latin America". *Economic Inquiry*, 51 (1), p. 16-30.

[21] Ferreira, P. F. and S. Pessoa, 2007. "The Effects of Longevity and Distortions on Education and Retirement," Review of Economic Dynamics, vol. 10(3), pages 472-493.

[22] Ferreira, P.F. and Santos, 2013. "AIDS, longevity and long-run income," Applied Economics, vol. 45(15), pages 2117-2125.

[23] O. Galor and D. Weil (2002) "From malthusian stagnation to modern growth", *American Economic Review.*

[24] G. Hansen and E. Prescott (2002) "Malthus to Solow", *American Economic Review.*

[25] Hazan, M. 2009, "Longevity and Lifetime Labor Supply: Evidence and Implications", *Econometrica*, 77(6), pp. 1829-63.

[26] Herrendorf, B. and Valentinyi, À. (2012). "Which Sectors Make Poor Countries So Unproductive?," Journal of the European Economic Association, European Economic Association, vol. 10(2), pages 323-341, 04.

[27] Kaplan, Greg 2011, "Inequality and the Lifecycle", Working Paper series 11-014, PIER.

[28] Kalemli-Ozcan, S.; H.E.Ryder and D.N.Weil, 2000. "Mortality Decline, Human Capital Investment, and Economic Growth", *Journal of Development Economics*, 62(1): 1-23.

[29] Kuznets, Simon S. (1966) Modern Economic Growth: Rate, Structure, and Spread. New Haven, Yale Univ. Press.

[30] Kuznets, Simon S. (1971) Economic Growth of Nations, Total Output and Productive Structure. Cambridge, Harvard University Press.

[31] Lee, D. and Wolpin, K. (2006) "Intersectoral Labor Mobility and the Growth of the Service Sector," Econometrica, 74(1): pp. 1-46.

[32] Loayza, N., Fajnzylber, P. and C. Calderón, (2005), "Economic Growth in Latin America and the Caribbean: Stylized Facts, Explanations, and Forecasts" Washington, DC: The World Bank.

[33] Maddison, A. 2009, Historial Statistics of the World Economy: 1-2008 AD. Available on-line at: http : //www.ggdc.net/maddison/.

[34] McMillan, Margaret S. and Rodrik, D. (2011) "Globalization, Structural Change and Productivity Growth," NBER Working Papers 17143, National Bureau of Economic Research, Inc.

[35] B. Naughton (2007) "The chinese economy^: transitions and growth", *MIT press.*

[36] K. O'Rourke and J. Williamson (2005) "Trade knowledge and the industrial revolution", *The Institute for International Integration studies.*

[37] S. Parente and E. Prescott (2000) "Barriers to Riches", *MIT press books.*

[38] K. Pomeranz (2000) "The great divergence: China, Europe and the making of the modern world economy", *Princeton University press.*

[39] Restuccia, D. and Vandenbroucke, G. 2013 (a), "The Evolution of Education: A Macroeconomic Analysis", *International Economic Review,* Volume 54(3), pp. 915-936.

[40] Restuccia, D. and Vandenbroucke, G. 2013 (b), "A Century of Human Capital and Hours", *Economic Inquiry, Volume* 51(3), pp. 1849-1866.

[41] Restuccia, D. and Vandenbroucke, G. 2013 (c) "Explaining Educational Attainment across Countries and over Time".

[42] Rogerson, R. (2005) "Structural Transformation and the Deterioration of European Labor Market Outcomes," National Bureau of Economic Research, Working Paper No. 12889, February.

[43] Rostow, W. W. (1971) The Stages of Economic Growth. Cambridge, Cambridge University Press.

[44] Soares, R., Mortality Reductions, Educational Attainment, and Fertility Choice," *American Economic Review*, 2005, 95(3), pp. 580-601.

[45] Soares, R. 2006. "The effect of longevity on schooling and fertility: evidence from the Brazilian Demographic and Health Survey," Journal of Population Economics, Springer, vol. 19(1), pages 71-97, February.

[46] Zheng Song, Kjetil Storesletten, and Fabrizio Zilibotti (2011) "Growing like China", American Economic Review 101: 202–241.

[47] Timmer, M. e de Vries, G. (2009) "Structural Change and Growth Accelerations in Asia and Latin America: A New Sectorial Data Set," Cliometrica 3 (2), pp. 165-190.

[48] J. Ventura (1997) "Growth and interdependence", *Quartely Journal of Economics 112: 57-84.*