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WORLDWIDE RELOCATION OF PRODUCTIONS, WAGES, ECONOMIC GROWTH AND SOCIAL WELFARE

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Abstract

This thesis develops a model to show the effects of relocation of production activities from developed (North – the US) to developing (South – Brazil, Chile, China, Colombia, India and Mexico) countries on wage inequality, economic growth, and social welfare. Relocations improve the overall relative efficiency of production due to the enhancement in the worldwide allocation of resources, expanding demand for labor. They also dynamically affect the technological-knowledge progress and bias between countries. The bias, induced by the market-size and price effects decisively drags the inter-country wage inequality and economic growth. We proved that wages paid in less developed regions have been converging to the earnings paid in developed countries due to improvements in relocation levels and sensitivities, regardless of the scale effects. When relocation increases, the wage disparity between the US vis-a-vis South country decreases considerably, particularly in regions where relocation activities are already highly developed as China, India and Mexico. As the scale effects value boost and fluctuations in the relocation sensitivity occur, we perceive that China and India exhibit a greater impact on wage inequality. Relocation sensitivity also leads to positive impacts on economic growth. As the parameter value rises, an enhancement in the dependent variable is visible, especially in the presence of a price effect. Brazil, Colombia and Mexico reveal a considerable increment on economic growth when compared to others regions, where a significant boost in relocation sensitivity would be necessary for this variable to increase remarkably. Concerning welfare, we concluded that the results fluctuate around a long-term stationary mean, except in China, India and Mexico, where there is a slight increase in welfare, with the exclusion of recession years. However, a rise of relocations causes satisfactory impacts on consumers' welfare, particularly like China, India and Colombia, where the estimated values of relocation sensitivity to consumption are higher.

Keywords: North-South model; Relocations; Technological knowledge; Wages; Growth; Welfare.

JEL Classification: F16; J24, J31, L24, O33

Resumo

Esta dissertação desenvolve um modelo que demonstra os efeitos relativos à desigualdade salarial, crescimento económico e bem-estar social face à relocalização das atividades produtivas de países desenvolvidos (Norte – EUA) para países em desenvolvimento (Sul – Brasil, Chile, China, Colômbia, Índia e México). As relocalizações melhoram a eficiência relativa da produção devido ao aumento da alocação mundial de recursos, expandindo, assim, a procura por mão-de-obra. Esta atividade afeta também o progresso do conhecimento tecnológico e o enviesamento entre países que, provocado por efeitos de mercado e preço, altera a desigualdade salarial e o crescimento económico entre regiões. Neste trabalho provamos que os salários entre países desenvolvidos e em desenvolvimento têm vindo a convergir, devido a melhorias nos níveis de relocalização e sensibilidades, independentemente dos efeitos de escala. Quando a relocalização aumenta, a desigualdade salarial diminui, particularmente em regiões onde as relocalizações são extremamente elevadas, como a China, Índia e México. À medida que o valor dos efeitos de escala aumentam e ocorrem flutuações na sensibilidade de relocalização, observamos que a China e a Índia são as que sofrem um maior impacto na desigualdade salarial. Esta sensibilidade origina, também, a consequências positivas no crescimento económico. Se o valor do parâmetro aumentar é visível uma melhoria considerável na variável dependente, especialmente na presença do efeito preço. O Brasil, Colômbia e México são os que apresentam um progresso mais notório no crescimento económico comparativamente aos restantes países. Relativamente ao bem-estar, concluímos que os resultados oscilam em torno de uma média estacionária de longo prazo, exceto para a China, India e México, onde ocorrem ligeiros aumentos, com exceção do período de recessão. Contudo, um aumento da relocalização provoca, sempre, impactos satisfatórios no bem-estar dos consumidores, especialmente na China, Índia e Colômbia, onde os valores estimados da sensibilidade de relocalização ao consumo são mais elevados.

Palavras-Chave: Modelo Norte-Sul; Relocalizações; Conhecimento tecnológico; Salários; Crescimento; Bem-estar.

Classificação JEL: F16; J24, J31, L24, O33

Contents

1 Introduction **1**

2 Literature review **5**

2.1 Globalization and relocation 5

2.2 Offshoring 7

2.3 Relocations and productivity 9

2.4 Relocations and wages 11

2.5 Relocations and economic growth 15

3 Measuring offshoring **18**

4 Theoretical model **22**

4.1 Preferences, technology and prices 22

4.2 Directed technological change 27

4.2.1 R&D technology and technological-knowledge bias 27

4.2.2 Endogenous technological-knowledge bias and inter-country wage inequality 29

4.2.3 Endogenous technological knowledge and economic growth 30

4.3 Macroeconomic aggregation 32

5 Quantitative results **33**

5.1 Calibration and data 33

5.2 Theoretical measure of relocations and inter-country wage inequality 36

5.3 Relocations and economic growth 44

5.4 Relocations and welfare 47

6 Econometric model **50**

7 Concluding remarks **53**

List of Figures

Figure 1 Inter-industry relocation values between the North and the South 21

Figure 2 Wage inequality and relocations when $\gamma_L = 0$ and $\widehat{\mu}_{China} = 5.8178$, $\widehat{\mu}_{India} = 5.3470$, $\widehat{\mu}_{Brazil} = 4.5860$, $\widehat{\mu}_{Colombia} = 3.0711$, $\widehat{\mu}_{Chile} = 2.4794$ and $\hat{\mu}_{Mexico} = 5.0053$ 37

Figure 3 Wage inequality and relocations when $\gamma_L = 0.5$ and $\widehat{\mu}_{China} = 5.8178$, $\widehat{\mu}_{India} = 5.3470$, $\widehat{\mu}_{Brazil} = 4.5860$, $\widehat{\mu}_{Colombia} = 3.0711$, $\widehat{\mu}_{Chile} = 2.4794$ and $\hat{\mu}_{Mexico} = 5.0053$ 39

Figure 4 Wage inequality and relocations when $\gamma_L = 1$ and $\widehat{\mu}_{China} = 5.8178$, $\widehat{\mu}_{India} = 5.3470$, $\widehat{\mu}_{Brazil} = 4.5860$, $\widehat{\mu}_{Colombia} = 3.0711$, $\widehat{\mu}_{Chile} = 2.4794$ and $\hat{\mu}_{Mexico} = 5.0053$ 40

Figure 5 Continuous annual growth rate of wage inequality, $\frac{w_N}{w_S}$ between the first and the last year under analysis, according to different relocation sensitivities, μ, and scale effects, γ_L 44

Figure 6 Average economic growth values, according to different relocation sensitivities, μ, and scale effects, γ_L 46

Figure 7 Welfare values according to the inter-industry relocation measure, real economic growth rate and $\widehat{\kappa}_{China} = 0.9357$, $\widehat{\kappa}_{India} = 0.3889$, $\widehat{\kappa}_{Brazil} = 0.1435$, $\widehat{\kappa}_{Brazil} = 0.1435$, $\widehat{\kappa}_{Colombia} = 0.4146$, $\widehat{\kappa}_{Chile} = 0.0716$ and $\widehat{\kappa}_{Mexico} = 0.0301$ 49

List of Tables

Table 1 Parameter values and exogenous variables 36

Table 2 ln(offshoring) - trend behavior and growth rate of relocation activity in the period 1997 and 2017 for China, India, Brazil, Colombia, Chile and Mexico 70

Table 3 Estimates of the parameters using the SEM, 2SLS 71

Table 4 Welfare - trend behavior in the period 2000-2017 for China, India, Brazil, Colombia, Chile and Mexico 72

Table 5 Estimation of the parameters using the SEM, 2SLS 73

1 Introduction

Over the past few decades, in particularly, since the 1980s, the world economy has become progressively more connected and cohesive. Part of this convergence was due the process of production relocation (hereinafter relocations), through, for example, offshoring, motivated by developed countries – Lee and Vivarelli (2006), Mattila and Strandell (2006) Roza et al. (2011). Relocation has been the main driver of economic globalization and is seen as the decision to shift all or part of the production, originally produced by an advanced country (the North, N), to a less industrialized country characterized by lower incomes (the South, S) – Pennings and Sleuwaegen 2000, Brouwer et al. 2004, Alcalá and Solaz 2018a. The most complex and skill-intensive tasks, which are produced by skilled workers, are mainly located in N, especially in the United States (US) which has even significantly increased investment in R&D – Antràs et al. (2006) and Farole et al. (2018). Indeed, during the decade 1999-2009, for example, this powerful country increased R&D expenditures from 8.7% to 12.7%, respectively – Arkolakis et al. (2018). Routine and standardized activities, which require only unskilled workers, are progressively more processed in less developed countries such as Brazil, Chile, China, Colombia, India and Mexico – Antràs et al. (2006) and Farole et al. (2018). It is not surprising, therefore, that in recent years several studies have found that imports by developed countries of intermediate goods from less industrialized countries have increased significantly, mainly due to the relocation of firms from N to S. Looking at the most important Southern countries in this process, China was a global producer of about 2.5% of all intermediate goods used in manufacturing in 1995 and this figure increased by about four times, exceeding 10% of all intermediate goods in manufacturing in 2009. The share of imports of intermediate goods from other southern countries is considerably lower but has also improved – Wolszczak-Derlacz and Parteka (2018), and our figures below.

According to the literature, relocations can be seen as a global tactic that has a massive impact on resource efficiency. It improves the competitiveness of firms in a globalized economy as it increases the likelihood of business expansion into international environments (Pennings and Sleuwaegen 2000, Brouwer et al. 2004, Sleuwaegen and Pennings 2006, Mattila and Strandell 2006) and, by promoting better resource efficiency, it leads to lower labor cost expenditures as production tends to be relocated to regions with low wages and abundant unskilled labor (Pennings and Sleuwaegen 2000, Sleuwaegen and Pennings 2006). In addition to this immediate improvement in production capacity (Brouwer et al. 2002), as firms that relocate production tend to be more productive (Oi and Idson 1999, Mitra and Ranja 2007, Harrison and Rodríguez-Clare 2010, Fosse and Maitra 2012), increased efficiency improves wage conditions (Antràs et al. 2006) and increases resource availability (Roza et al. 2011), which, in turn, encourages innovation, especially in developed countries. The positive effect on technical progress (Mattila and Strandell 2006, Arkolakis et al. 2018), but also on human capital (Wagner 2011), promotes economic growth and thus the improvement of people's standard of living or welfare (Olsen 2006). Both the static effects associated with the improved global resource allocation (efficiency) and the dynamic effects associated with economic growth, wage conditions are substantially improved (Antràs et al. 2006). It is, therefore, clear that due to improvements in communication systems (Cheung et al. 2008) and advances in knowledge diffusion (Kang et al. 2010, Gries et al. 2017), the benefits are shared on a global scale through the global adoption of best practices. These lead to improvements in learning externalities (Schwörer 2013) and promote considerable productivity increases with a positive impact on all macroeconomic variables (Cheung et al. 2008, Schwörer 2013).

In particular, economic growth is a topic widely addressed by several authors because the sustained improvement of living standards depends on it (Acemoglu 2012). It is certainly strongly influenced by R&D activities (Jones 1995, Acemoglu 2012), which, in turn, are positively affected by globalization (Garicano and Rossi-Hansberg 2012). Advanced countries, with innovative capacity, can grow faster than a less developed country (Kaldor 1957, Gries et al. 2017, Grossman and Helpman 1991). However, through relocations, the latter countries benefit and influence the growth of the former countries (Grossman and Helpman 2018, Rodríguez-Clare 2010), due to knowledge spillovers (Naghavi and Ottaviano 2009b) and improved absorption capacity (De Mello Jr. 1997), which allows a higher level of technological knowledge diffusion (Gries et al. 2017).

To assess these impacts, we have developed a Direct Technical Change (DTC) growth model that describes the economic configuration of the world economy composed of two countries, the North and the South. We consider that an aggregate final good is used for consumption and investment. This is an aggregate of North and South production, with in each country a large number of labor competitive firms and a continuous set of non-durable intermediate goods to carry out production. The relocations take form of transfers of some of these companies from North to South, and these firms are more efficient and want to benefit from the wages practiced in the South. Thus, the production of final goods in the South may be done by domestic firms or by firms resulting from the relocation of production from North to South, namely due to international vertical outsourcing, vertical relocation or foreign direct vertical investment (FDI).[1] In turn, each intermediate goods sector is composed of a continuous set of monopoly producers, each using a particular design sold by the R&D sector. In this process, we consider the possibility of the presence or absence of scale effects, measured by market size. Hence, the profitability of R&D can be induced by the market-size channel (with the scale effects; see Acemoglu 2002), or by the price channel (with the removal of scale effects; see Acemoglu 2002).

Before presenting the main analytical results of the model, we have determined an offshoring measure, which is a proxy for the relocation level measure, to understand the dimension of the phenomenon.[2] Considering this measure, we observe, as expected, that China, India and Mexico are the regions with the highest values. We calculate some quantitative results from the previous analysis. In particular, we started by measuring the magnitude of the impact of relocations on cross-country wage inequality according to the presence or the absence of scale effects. Taking into account the *market-size effect* or the *price effect*, we evaluate how the inter-country wage inequal-

[1]The word "vertical" means that firms perform different products in different countries. Moreover, when a firm outsources, it buys from a third part or service to produce itself and thus it does not necessarily mean that the good is outsourced abroad, although it can be and is considered by us throughout the research. For instance, the US General Motors can outsource the production of a certain car part to a Chinese firm. In turn, when a firm offshores, it shifts the location of a service or production of a part to a location abroad, usually resulting in a partnership/agreement or minority detention. For example, if General Motors controls a significant proportion, but by less than 50%, of a Chinese firm and shifts the production of a car part to this firm in China, it is offshoring. Lastly, relocation can occur through the installation of foreign (multinationals) firms that control and manage domestic firms via cross-border acquisitions of existing firms or through the establishment of new firms; in this case the multinational controls the local firm; e.g., General Motors can create a firm in China, thus controlling more than 50%, to produce a specific car part.

[2] We have also conducted a literature review on the main topics covered in this paper, but in view of the paper's dimension it is only available on request from the readers to the authors.

ity, economic growth and social welfare, in each pair of regions, react according to a few estimated values of relocation sensitivity to wage inequality and economic growth, and of relocation sensitivity to consumption (social welfare). We also examine the path of the welfare. Bearing in mind the theoretical model, it is relevant to analyze and explore the behavior of these macroeconomic variables motivated by the impact of relocation activities. Wage inequality between North and South countries are expected to decrease as relocation levels and sensitivity become more pronounced, and the expansion of this activity increases as scale effects decrease. As regards economic growth and social welfare, these variables are expected to increase sharply as the sensitivity parameter becomes higher. Furthermore, this increase should be more pronounced in the absence of scale effects.

The current shock caused by the Covid-19 pandemic has led to the closure of the borders. It will undoubtedly lead to a reduction in relocations, representing, at this level, a trajectory contrary to what the world has been witnessing, and it is expected to represent a step backwards in the globalization process.

To support the conclusions obtained through the theoretical model and quantitative results, we decided to estimate the relocation sensitivity parameters through the simultaneous equation model (SEM). We adopt this approach in order to mitigate the estimation problems of endogeneity revealed in the relocation variable and, to analyze the cause-effect relationship between the dependent - wage inequality and social welfare - and independent variables.

The rest of the dissertation is organized as follows. The Section 2 covers the literature review, where we analyze topics related to globalization and relocation, and the interaction between the offshoring activity and productivity, wages and economic growth between North and South countries. Section 3 revisits our offshoring measure based on the approach of Hijzen and Swaim (2007). Section 4 presents our theoretical model that reports the economic set-up of the world economy composed by the North and the South country and contains the relative return on North-labor, which is the wage inequality measure, the economic growth rate and the social welfare function. Section 5 describes the data used, the calibration and illustrate the quantitative results by using graphs. Section 6 states the models used for the empirical research and exhibits the results and interpretations of the regressions coefficients. Lastly, Section 7 concludes.

2 Literature review

2.1 Globalization and relocation

The international relocation is defined as the decision to shift all or just a part of the production (Brouwer et al. 2004) initially carried out in a developed high-income country to an alternative country, characterized by lower incomes (Alcalá and Solaz 2018a, Pennings and Sleuwaegen 2000) and become a meaningful way to improve the competitiveness of firms (Sleuwaegen and Pennings 2006). Over the last decades, developing countries have substantially increased their participation and integration in global markets due to the globalization process, which has led to an improvement in the reallocation of production (Alcalá and Solaz 2018b). This procedure was mainly driven by the deregulation of the markets and technological advances experienced in developed countries, which led to different impacts on economy and society (Mattila and Strandell 2006, Lampón et al. 2017). The dynamics of production and employment were significantly affected in all countries (Alcalá and Solaz 2018a), and the transportation and communication linked to the efficient logistics (World investment report 2018) made possible to produce final goods in countries far from where the ideas were created (Arkolakis et al., 2018). This situation has driven developing countries to better connect to global value chains (World investment report 2018) and greater specialization in production (Arkolakis et al. 2018). However, this new economic age could also result in severe economic problems and more inequality (World investment report 2018).

According to the literature, some several measures and forces lead firms to expand their business to international environments (Pennings and Sleuwaegen 2000, Brouwer et al. 2004, Mattila and Strandell 2006). Firstly, to find new resources and skills that create access to new technologies, specialized skills, decent infrastructure or raw materials (Mattila and Strandell 2006) that allow firms to improve technological advantages and higher operational flexibility (Pennings and Sleuwaegen 2000). Second, the need for expansion is necessary to achieve new markets that stimulate the firm's potential growth (Dicken and Lloyd 1977, Hayter 1997, Pennings and Sleuwaegen 2000, and Pellenbarg et al. 2002, Brouwer et al. 2004, Mattila and Strandell 2006). In third place, firms can also take advantage of cost conditions in other countries, where production is less expensive (Pennings and Sleuwaegen 2000). These conditions are directly linked to wage differentials where, according to studies provided by Motta and Thisse (1994), Grilo and Cordella (1998), Collie and Vandenbussche (2001), the disparity between home and host country need to be large enough (Sleuwaegen and Pennings 2006), scale economies, energy prices, local incentives (Brouwer et al. 2002) and lower labor costs followed by abundant-labor. Frequently, firms prefer to reallocate production based on cost savings when the technologies use are labor intensive and productivity, compared to other sectors of the economy, is low. In this case, high unit labor costs oblige firms to close or redirect their production to countries with low labor costs (Pennings and Sleuwaegen 2000, Sleuwaegen and Pennings 2006). When the last solution occurs, each region acts according to its comparative advantage. South countries focus on the production of labor-intensive products while North countries specialize in skill-intensive outcomes (Kurata et al. 2020) that require infrastructures, institutions, human and physical capital (Hidalgo et al. 2007). This process will encourage the growth of vertical specialization and will affect the impacts on wages, welfare and will bring efficiency gains (Arkolakis et al. 2018, Kurata et al. 2020). The effects of production on remunerations and welfare are founded on offshoring models produced by some authors such as Feenstra and Hanson (1996), Kohler (2004), Markusen (2005), Rodríguez-Clare (2010), Baldwin and Robert-Nicoud (2014), but the results are not precise (Kurata et al. 2020). However, being a recent phenomenon, specialization can bring several problems related to economic growth because countries that specialize in labor-intensive are afraid that low levels of innovation affect their growth. In contrast, countries with high levels of innovation fear that the availability of good middle-income occupations is reduced (Arkolakis et al. 2018).

Nevertheless, mainly smaller firms, do not take advantages from locating their production in countries where production costs are lower because sometimes the trade and sunk costs are excessively high (Pennings and Sleuwaegen 2000, Arkolakis et al. 2018).In this sense, before the North-countries relocate their production, they need to evaluate the characteristics of the geographic region in order to understand which area provides the highest competitive advantage. The location of production is an important factor because, for example, some organizations are knowledge-intensive and may prefer to be based in regions where there is higher repercussions of knowledge. Concerning territorial embeddedness, the higher the distance between nations, the more challenging it is to allocate tacit knowledge, which leads to worse performance and higher levels of instability for the organization (Knoben et al. 2008).

Countries located in Eastern Europe, Asia and South America are the most requested to relocate production. These nations offer good products, with good quality at low-cost prices and have been shown a fast economic growth because they have participated more in education, invested more in research and development (R&D) and increased the import of intermediate goods, in order to catch up with the North countries. Hereupon, they have been able to specialize in necessary products and in more innovative and internationally competitive outcomes (Mattila and Strandell 2006, Seker 2012). According to the literature, mainly global companies experience a larger productivity, faster growth, higher levels of innovation and are more likely to introduce better technologies than non-traders firms (Seker 2012).

Vernon (1966) was one of the main drivers of the study of international relocation of production. This author developed a theory based on the product life-cycle where were approached the dynamics of production reorganization between different regions. At first, products are developed in North countries and exported to South countries. When the production process becomes sufficiently standardized, South countries become the ideal choice for relocating products and, therefore, part of the production is shifted to these countries. Thereby, these dynamics induce a progressive increase in the process of international relocation of production. After this first approach, several authors such as Krugman (1979), Dollar (1986), Grossman and Helpman (1989), Antràs (2005), and Arkolakis et al. (2018) continued the analysis (Alcalá and Solaz 2018b).

2.2 Offshoring

Offshoring is seen as a specific type of relocation, (Mattila and Strandell 2006) mainly, chosen by firms when the economic growth rate of the home country is damaged (Naghavi and Ottaviano 2009a) and when the firm's net gain exceeds costs (Marin 2006). Offshoring was a strategy that started to be introduced in the late seventies and since then several studies covered by some authors such as, Hummels et al. (2001) or Amiti and Wei (2004) have documented their fast growth

(Schwörer 2013) and have verified the global expansion of the intermediate goods trade (Cheung et al. 2008). Therefore, this approach is characterized as the relocation of tasks that were earlier developed by North countries are now produced in South countries and then sent to the home country in the form of imported intermediate inputs and transformed into final products (Hijzen and Swaim 2007). The final products market can only be located in industrialized countries since only these nations have the accumulated knowledge to perform R&D and to produce differentiated goods (Naghavi and Ottaviano 2009a). This process can be used to overcome difficulties associated with limited resources, decrease innovation costs, increase efficiency gains (Roza et al. 2011), improve the structure of earnings in both countries (Antràs et al. 2006), stimulates productivity growth and the investment in human capital (Wagner 2011). In the long-run, offshoring can increase economic growth and employment levels (Mattila and Strandell 2006).

This strategy brings several benefits to consumers' purchasing power, since products are sold at cheaper prices (Cheung et al. 2008, Naghavi and Ottaviano 2009a). Thus, due to the rise of the global supply base, competitive pressure tends to increase, and fluctuations in relative prices are visible (Cheung et al. 2008). According to Rodríguez-Clare (2010), based on the Ricardian model, in short-run, relocations always benefits the low-wage country, but can damage the high-wage country. However, in the long-run, when countries adjust their efforts to improve this process, the North countries always gain, whereas South countries may experience losses if they do not follow developed countries (Rodríguez-Clare 2010). In the long-run, advanced countries experience economic benefits through positive productivity variations induced by knowledge spillovers, reductions in costs, creation of high-quality jobs, increase in real wages and growth in domestic consumption, which leads to an improvement in their living standards (Olsen 2006).

The production of offshoring is based on the theory of comparative advantages developed by David Ricardo (1817). The author argues that if two different countries specialize in the production of goods where they have a relative advantage, both will be able to profit and the aggregate production will rise which leads to an improvement in trade relations between countries. However, this theory, according to Schumer and Roberts (2004), is no longer valid, due to the mobilization of factors of production (Marin 2006).

The firm located in the home country before relocating its production takes into account, mainly, lowest production costs, wages and transport expenditures (Marin 2006), improvements in information and communication technology (ICT) and expansion of capacity and quality of services (Cheung et al. 2008). When there is a decrease in the costs of production, transportation and communication, caused by technological changes (Rodríguez-Clare 2010), automation of activities and reductions in regulatory burdens in developed countries (Bandyopadhyay et al. 2017), the growth of offshoring increases because the intermediate goods are more easily traded between countries. In this case, firms can take advantage of the production cost savings obtained in low wage countries without losing the gains from specialization (Grossman and Rossi-Hansberg 2008) and may even increase the international division of labor according to the comparative advantages (Wagner 2011).

Thus, offshoring, according to Rodríguez-Clare (2010), leads North workers shift their specialization to activities linked to innovation, which reduces the opportunity cost of innovate (Bernard et al. 2020). Furthermore, developed countries will be able to provide more resources available for these activities which means an increase in R&D investment (Michel and Rycx 2014) and, consequently, a strengthening of the domestic economy, higher technology transfer, spillovers and larger competitiveness at home (Castellani and Pieri 2013).

Broadly and due to skill-biased technological progress, routine activities are offshored while difficult tasks are done locally. Hereupon, North countries will focus their demand for skilled workers, while South countries will increase their demand for unskilled workers, essential to elaborate labor-intensive tasks (Antràs et al. 2006, Farole et al. 2018). This technological change that leads to the demand for different skills between countries induces, an overall, increase in productivity and raise the relative wage of skilled labor and unskilled labor in developed and less developed regions, respectively, which means an increase in aggregate wages in both locations (Farole et al. 2018, Feenstra 2010).

2.3 Relocations and productivity

It is more than proven on theoretical grounds and, according to Amiti and Wei (2009) and others, that offshoring provided an improvement in productivity gains through different channels.

First, static efficiency gain can arise when offshoring firms specialize (Cheung et al. 2008) since they concentrate their most productive activities at home (Kang et al. 2010) and relocate the less efficient parts of their production stage (Amiti and Wei 2006). Second, offshoring may also be followed by restructuring measures, which decrease inefficiencies (Schwörer 2013). This process can force firms to reorganize their workforce, adopt new practices and improve their communication system (Cheung et al. 2008) at a lower cost (Amiti and Wei 2009). Third, productivity may also be improved by learning externalities due to the collaboration with developed countries (Schwörer 2013). Partnerships between countries act as knowledge diffusion that induces developing countries to acquire knowledge about the technologies used abroad (Kang et al. 2010, Schwörer 2013). Fourth, the adaptation of more complex tasks for technologically advanced organizations allows these firms to innovate and raise their productivity (Cheung et al. 2008, Schwörer 2013). Lastly, efficiency gains may also arise if there is an improvement in the quality of the use of new varieties of intermediate inputs (Amiti and Wei 2009). However, in practice, all channels mentioned above are difficult to distinguish. They are all seen as direct channels of productivity gains. Nevertheless, it is also essential to take in consideration indirect channels, which are linked to productivity spillovers (Michel and Rycx 2014) and geographical proximity that can be crucial for a better knowledge transmission (Castellani and Pieri 2013).

There is theoretical and empirical research that analyze the impact of offshoring on productivity. Fixler and Siegel (1999) approached this impact empirically and realized that in the short-run this process could lead to reductions in efficiency, but in the long term, improvements would be expected. On the same line, Baldwin and Robert-Nicoud (2007) and Grossman and Rossi-Hansberg (2008) proved that the offshoring processes benefits the productive activity. Egger et al. (2001) and Egger and Egger (2006) evaluated the impact of offshoring materials on the productivity of twenty Austrian manufacturing industries and concluded that, in the long-run, the increase was significant and positive. Mann (2003), Criscuolo and Leaver (2005) and Görg et al. (2008) decided to go further linking technology improvements to globalization and argued that services offshoring has positive impacts on the innovation sector that lead to improvements in productivity. Amiti and Wei (2004, 2009) concluded that an increase of one percentage point in services offshoring, leads to a growth in labor productivity in US manufacturing industries.

Similar results were obtained by Crinò (2008) for a panel of nine EU countries and by Winkler (2010) for Germany. Kurz (2006) proved that offshoring firms in the US experience higher levels of productivity compared to non-offshoring firms. With regard to Asian countries, such as Japan, Ito and Tanaka (2010) and Hijzen et al. (2010) also found that offshoring promotes the productivity of firms. Regarding developing countries, Kang et al. (2010), using an empirical model, proved that both material and service offshoring have positive effects on the productivity of South countries.

Thus, it is possible to predict that productivity changes positively according to the intensity of offshoring. In this sense, as the offshoring technology improves, the costs associated with trade, innovation and production decrease in both types of countries that results in higher productivity (Bernard et al. 2020, Grossman and Rossi-Hansberg 2008). Besides, productivity is considered an important driver of economic growth, and it also has positive implications for the labor market (Schwörer 2013).

2.4 Relocations and wages

A pertinent issue introduced by several authors has been to what extent offshoring activities affect labor markets. Research carried out show that firms involved in offshoring activities become more productive, competitive, raise their market shares, which leads to an increase in employment and wages (Balsvik and Birkeland 2012). However, developed countries have been the main focus of experts' analysis because they are the most affected by the consequences of relocation (Wolszczak-Derlacz and Parteka 2018). Offshoring can affect employee's wages through different main channels, such as productivity, as mentioned above, skill composition or rent-sharing.[3] All of these channels are relevant to explain wages differences and are related; however, the most considered channel that reveal more outcomes is skill composition (Fosse and Maitra 2012).

[3] Rent-sharing is seen as an improvement in the negotiation between the firm and workers (Budd et al. 2005) where their employees bargain over particular firm rents that can lead to an increase in wages (Fosse and Maitra 2012). Goos and Konings (2001), Oyer (2004) and Sethupathy (2008) have found several evidences that, through this channel, workers experienced wage improvements.

During the 1980s and part of the 1990s, many changes occurred in the labor market, mainly in North countries. One of the main modifications was noted in the composition of employment. Industrialized countries shifted their preference in favor of skilled workers, affecting the conditions of less qualified employees (Crinò 2009, Ernst and Sánchez-Ancochea 2008). However, offshoring does not affect wages and employment levels in the same way because it depends on the country labor market features (Helpman 2017). If we observe the US manufacturing sector as an example, during the period 1980-1992, we conclude that there was a significant growth of skilled workers and an increase in their wages. More specifically, non-production employees have earned 4 percentage points in the total wage bill (Crinò 2009) and, according to Berman et al. (1994) the US improved its demand for skilled workers by 70%. In the same way, in 1999, Feenstra and Hanson note that, between 1979 and 1990, the rise in offshoring activities could justify 15% to 40% of the increase in the US employees with more skills.

This change in the composition of workers occurs in part due to the high wage value of unskilled employees and high production costs in North countries. As the wages of workers in South countries are lower, there is an incentive for developed countries relocate part of their production abroad. Thus, this process leads to more standardized tasks to be performed in developing countries and more complex tasks to be performed in developed countries (Hummels et al. 2018). Therefore, the demand for skilled employees will raise in the North, and the demand for unskilled employees will increase in the South. Several researchers have studied the explanations for the shift of skill-composition, and some of them described this change through the Stolper–Samuelson theorem (Crinò 2009). Samuelson theorem was used to analyse the repercussions of trade in labor markers, more specifically, in changes in products prices and wages (Wolszczak-Derlacz and Parteka 2018). According to this theory, if free trade opens up between the two types of countries the less industrialized countries specialize in low-skill-intensive products which reduces the relative price of low-intensive goods and increases the wages of this type of employees (Helpman 2017). About developed countries, the theorem reveals that specialization will focus on the most complex tasks and, therefore, offshoring increases the relative price of the product whose construction is not offshored; that is, the skill-intensive product. (Mitra and Ranjan 2007). Under the circumstances, the Stolper-Samuelson Theorem expects that the earnings of low-skilled employees should deteriorate in North countries relative to the earnings of high-skilled employees, which should growth. All changes that have occurred can be amplified by fluctuations in country's trade policy, such as trade liberalization, or through variations that occur in other countries that trade on foreign markets (Helpman 2017).

According to Acemoglu (1998, 2002), and others, one of the main reasons that led to the shift of relative demand for skilled workers, in North countries, was the acceleration of technological progress. Hence, an increase in technological progress may explain the change composition of employment that occurred in the 1980s in the U.S. Technological advancement tends to complement employees with more qualifications and to substitute employees with lower levels of education. Therefore, the labor demand may be biased in favour of qualified workers (Acemoglu 1998, 2002, Crinò 2009). Initially, the impact of this progress, can negatively affect the labor market. However, as the proportion of offshoring increases, the effects provided by technological change will "become an equalizing force" and the wages of unskilled workers begin to rise and become stable in developed countries and, the benefits for workers in both type of regions also increases (Acemoglu et al. 2015). Also, Bhagwati et al. (2004) proved that offshoring might increase economic expansion and, when the process occurs, the activities in each country become more productive and lead to better wages in all sectors. Rodríguez-Clare (2010) also supported a view similar to the one we addressed. According to this author, offshoring can provide, in the short-run, only positive effects for the developing country. Nevertheless, in the long-run, when the speed with which resources can be offshored across production and research is high, and offshoring costs decrease, the effects are always positive for the industrialized country (Rodríguez-Clare 2010). Thus, it is possible to observe that, when offshoring is limited, wage inequalities between countries are notable, however, as offshoring activities intensify, the wage gap between both economies decreases (Acemoglu et al. 2015).

Several studies addressed this topic in an empirical and theoretical way. About developed countries, Feenstra and Hanson (1999) during the 70s and 80s, find that the real wages of unskilled employees were unaffected by this type of relocation. However, skilled workers experienced wage gains of 1 to 2 percentage points. Arndt and Kierzkowski (2003) proved that, in the short-run, the earnings of unskilled workers might fall but, over time, wages may increase under certain conditions. Karabay and McLaren (2010) claim that this type of relocation increases the volatility of wages, but the general equilibrium effects boost the expected earnings. Mitra and Ranjan (2007) build a theoretical model which proves that thanks to offshoring, the unemployment rate decreases and wages rise, in both types of countries. Grossman and Rossi-Hansberg (2008) and Melitz and Ottaviano (2008) show that offshoring activities may increase productivity and consequently, in the long-run, lead to wage gains for skilled and unskilled workers when the offshoring costs decline. Geishecker and Görg (2008) used data from Germany and concluded that in short-term offshoring reduced the real wage for low skill workers while it improved real wages for high skilled workers. Lommerud et al. (2009) showed that an increase in offshoring always leads to wages gains in the home country. In 2018, Wolszczak-Derlacz and Parteka, based on other research conducted by Lawrence (2010) and Ebenstein et al. (2014) proved that the wages of unskilled workers do not decrease significantly due to offshoring. Concerning to developing countries, Helpman (1984), McMillan (2010) and Balsvik and Birkeland (2012), concluded that relocations have positive effects on the labor markets, mainly on the wages of unskilled workers.

The differences in welfare and labor market between offshoring and non-offshoring firms are striking. Firms associated with offshoring activities tend to pay higher wages, have higher productivity rates (Fosse and Maitra, 2012) and are more likely to increase their profits (Sethupathy, 2013) when compared to non-offshoring firms. Oi and Idson (1999), Harrison and Scorse (2006) and Mitra and Ranjan (2007) show that more productive offshoring firms pay higher wages relative to domestic firms. Martins and Esteves (2006), follow employees who move to or leave foreign firms in Brazil between 1995 and 1999 and they discovered that workers who generally move from foreign [domestic] firms to domestic [foreign] firms receive a lower [better] remuneration. Harrison and Rodríguez-Clare (2010) report that many foreign enterprises established in developing countries provide better conditions and wages for workers, induced by improvements in productivity. Amiti and Davis (2012) based their conclusions on a theoretical model to understand how wages react when tariffs fall. As the output or input tariff decreases, the competition between firms increases and the enterprises, which are only linked to the domestic market are forced to pay lower wages. Therefore, firms that are related to offshoring activities increase their wages when compared to non-offshoring firms of the same industry.

2.5 Relocations and economic growth

Economic growth is a topic widely addressed by several authors, especially from the 19th and 20th century. During that period, mainly countries located in Western Europe experienced fast growth while many others have stagnated (Acemoglu et al. 2015). Nevertheless, due to globalization, the opening to trade and its expansion had experienced an increase leading to growth improvements in all countries (Helpman 2017). However, although globalization is the key driver of economic growth, this expansion "is not a smooth continuous process of accumulation" (Garicano & Rossi-Hansberg 2012).

There is a general agreement, carried out by several authors including Färe et al. (1994), Klenow and Rodriguez-Clare (1997) and Hsieh (2002), that innovation and technical change are the major factors that lead to crucial shifts in economic growth expansion (Jones 1995, Gries et al. 2017). Besides, the R&D-based models proposed by Dowrick and Nguyen (1989), Romer (1990), Grossman and Helpman (1991), Aghion and Howitt (1990), Barro (2014) and Jones (1995) also indicated that an increase in R&D investment leads to improvements in growth rates. In this sense, a society where labour change, adaptation and investment in new approaches occur fast will experience an acceleration in productivity and consequently will achieve higher growth rates (Kaldor 1957). For developed countries, where the economy has grown at a rate of approximately 1.5% in the past few decades, investments in new technologies and R&D, stimulated by changes in skill-composition work, educational attainment, globalization and offshoring, is seen as the main driver of production and growth. Developing countries are not able to invest in R&D as developed countries and, for this reason, they end up receiving, later, the technology originated in wealthy regions. Thus, their gains in productivity and growth reach different values when compared to industrialized countries (Gries et al. 2017, Grossman & Helpman 1991a).

In addition to innovation, human capital is also an essential factor when associated to investments in R&D and technological diffusion. Human capital is essential to find and adopt new innovative techniques in the most developed regions and, concerning developing countries, it proves to be important to adopt foreign technology (Gries et al. 2017). The comparative advantage of the US is reached from their relative abundance in human capital and, consequently, their capacity to originate and promote new ideas. Their investment in influential research institutes, universities and laboratories leads to a faster pace of innovation and, therefore, leads to higher rates of economic growth (Garner 2004). Some articles, carried out by (Romer 1989), Azariadis and Drazen (1990) and Barro (1991) showed positive correlations between the rate of human capital and real GDP growth.

Offshoring can provide to North countries a release of domestic resources, previously invested in unskilled labor activities, to create more innovative and sophisticated products that require R&D (Naghavi and Ottaviano 2009b). This release of resources leads to a higher rate of innovation in skill-abundant developed countries (Gao 2007). However, although the innovation rate is higher in industrialized countries when compared to less industrialized countries, offshoring always leads to improvements in economic growth (Davis and Naghavi 2011, Gao 2007) when associated with strong knowledge spillovers (Naghavi and Ottaviano 2009b) and low costs (Grossman and Helpman 2018; Rodríguez-Clare 2010).

Branstetter et al. (2019) reported the importance of offshoring for North countries, for example, for the US, and how the impact of this activity influence the expenditures in R&D. They showed that between 1999 and 2014, the expenses in this sector increased by 5.6% per year and offshoring was the main driver of R&D growth in countries that use new technologies intensively. In the same vein, Baily and Lawrence (2004) performed an estimate for 2015 and predicted that offshoring should have a positive impact on the economic growth for innovative countries. Mann (2006) Naghavi and Ottaviano (2009a) and Davis and Naghavi (2011) also studied the effects of relocations in the developed countries and concluded that these activities leads to an increase in innovation and, therefore, leads to higher rates of growth. Mbiekop (2010), using an endogenous growth model found that offshoring can increase the economic growth of the home country by increasing the accumulation of human and physical capital. However, authors such as Garicano and Rossi-Hansberg (2012) showed that even though technological advances, on the one hand, promote an expansion in economic growth, on the other hand, they can also lead to stagnation and, consequently, to a decline in the growth rate. The adoption of new technologies forces individuals to produce new techniques and accumulate knowledge. Nevertheless, when new technologies are previously well explored, it becomes more complex to innovate. Hereupon, it is possible to observe a positive correlation between offshoring activities and economic growth in countries attracted by innovation, when technological advances do not stagnate.

Thus, the North countries will increase their economic growth because their investments in the creation of new products rise while the South countries, specialized in products with intense standardization, will suffer negative impacts, in the beginning, and will grow slower (Alcalá and Solaz 2018b). In this sense, Acemoglu et al. (2015) argued that the standardization process is an essential part of a country's expansion. However, it can also be a barrier to growth, as it discourages innovation. Nevertheless, with globalization, trade openness, the existence of R&D and knowledge spillovers (Helpman 2017) and a satisfactory absorptive capacity (De Mello Jr. 1997) it is possible to achieve a greater technological diffusion (Gries et al. 2017) and a faster economic growth in these countries (Helpman 2017). In this sense, a reduction in trade costs such as transportation costs, tariff and non-tariff, cultural and institutional barriers improved these repercussions, which led to gains in specializations and, therefore, an increase in global economic integration and growth (Gao 2007).

Hereupon, Gao (2007), Kikuchi and Marjit (2011), Naito (2012) and Saito (2018) developed a North-South R&D-based growth model and proved that a reduction in the trade cost leads to an increase in the production of intermediate goods in developing countries and an expansion in the R&D sector for developed countries, which boosts the global economic growth rate. Furthermore, Naito (2012) also showed that a decrease in the trade cost stimulates the exports and imports of intermediate goods and optimize the welfare in both countries. Marjit and Mandal (2017) and Nakanishi and Van Long (2020) demonstrated that a boost in trade liberalization has strong positive implications for the economic growth in the North and South.

3 Measuring offshoring

The effective measurement of relocations is a complex task and has led several authors to test different approaches (Crinò 2009). Although many of them have been developed, most have struggled with several problems due to the data. Thus, the researchers decided to resort to "proxy" measures that allow us to estimate a relocation measure. A large part of relocation measures are focused on imports by foreign countries of intermediate goods or in the form of relocated service components (Bottini et al. 2007). Feenstra and Hanson (1999) propose to use imports of intermediate inputs as a proxy (Crinò 2009) and suggest the distinction between narrow and broad measures, where the first considers imported intermediate goods in a given industry, while the second considers imported intermediate goods from all industries (Foster-McGregor et al. 2013). In our analysis we are going to follow the approach of Hijzen and Swaim (2007) and consider a measure of broad relocations (or inter-industry relocations). Therefore, the (broad) measurement of inter-industry relocation S_i^B is carried out through the ratio between imported intermediate goods by industry i from all industries j, other than value added:

$$S_i^B = \frac{\sum_{j=1}^{J} G_{j \neq i}}{V_i} \tag{1}$$

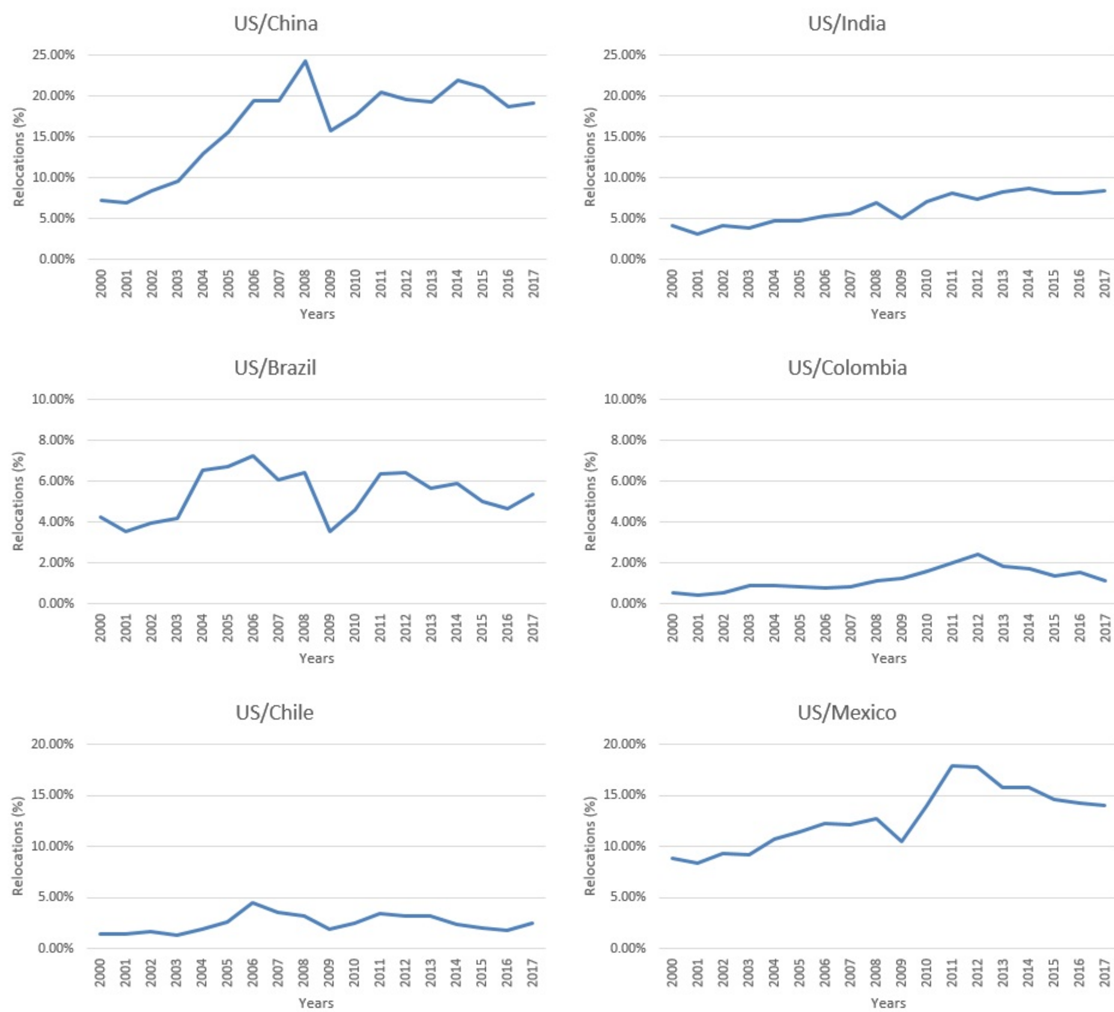
where B means broad measure, G is relative to imported intermediate goods from industry $j \neq i$ by industry i, and V refers to value-added. The dataset used for the quantitative analysis was obtained for the period between 2003 and 2017 and includes the US as the North and Brazil, Chile, China, Colombia, India and Mexico as Southern countries. The data of intermediate goods imported from the North to the South country were acquired from the World Integrated Trade Solution (WITS). The industrial classification broadly follows the STAN industry list, which is based on the International Standard Industrial Classification (ISIC), Rev 4. The agriculture, hunting, forestry and fishing (ISIC 01-03), the mining and quarrying (ISIC 05-09), the trade, repair of motor vehicles and motorcycles (ISIC 45-47) and the land transport and transport via pipelines (ISIC 49) were not included in our analysis. The dataset for the value added for the US were from World Bank databases and the sum of indicators used were the Industry (including construction), value added (% GDP) and the Services, value added (% GDP).

We compute the values for inter-industry relocations between the North and each South country since one of our first goals is to understand how the values of relocations behave over time and according to each pair of countries. In Figure 1, it is possible to observe that all countries experienced an increase in relocations between 2000 and 2017, with China and Mexico being the regions most affected by this activity. India was also a country that showed improvements in relocations, exhibiting a growth of 4.28 percentage points (pp) between the time interval mentioned before. With regard to Brazil and Chile, both regions experienced improves around 1.15 pp between the beginning and the end of the period studied. The country with the smallest relocation value and the lowest growth between the years analyzed was Colombia where the differences between 2000 and 2017 were about 0.56 pp.

To better understand the behavior of relocations, we decided to estimate the trend and continuous growth rate of this activity in the period 1997 to 2017 – see Appendix C. To analyze the trend behavior and estimate the growth rate of relocations, we divided the period into three subsamples: before (1997 to 2007), during (2008 and 2009) and after (2010 to 2017) the crisis, and we introduce as explanatory variables: trend, additive dummy variables for the period during and after crisis and also, multiplicative dummy variables. *Dcrisis* is a binary variable that assumes value 1 in the recession interval $[2008, 2009]$ and zero, otherwise and *Dafter* that acquires the value 1 after the crisis period $[2010, 2017]$ and zero, otherwise. To detect the trend behavior, we started by examining the existence of structural breaks through the Chow test. According to the specification *(a)*, exposed in Appendix C, we reject the null hypothesis in all the estimations for a level of significance of 1% for China, Colombia, Chile and Mexico and, a level of significance of 5% for India and Brazil. Therefore, these structural breaks are exhibit in all countries. Considering the results obtained in specification *(a)*, we estimate the models revealed in specifications *(b)* and *(c)*, and we conclude that the trend variable is statistically significant for all countries. In other words, all of these regions show an increase or decrease tendency, over time. The estimations in China and India show that the relocation activity before the crisis grew at a rate of 13.13% and 4.58%, during the recession both suffered a decline around 43.69% and 32.63% and, in the third period, this activity returned to a growth rate of 0.57% and 1.87%, respectively. In turn, Brazil showed an increase before the crisis of 6.17%, in the second period, this region revealed a decline of 59.27% and, after the recession exhibited a deterioration of 1.44%. Colombia, unlike the other regions, does not show a reduction in the growth rate of relocation activity in the crisis interval. Thus, until the third period, the growth was 6.30% and in the last phase, the rate suffer a decline of 6.77%. Lastly, Chile and Mexico demonstrate an increasing trend in the first period of 11.95% and 3.76%, respectively, and a decreasing trend in the following periods. During the recession, Chile and Mexico experienced a decline of 52.98% and 19.78% and, after the crisis showed a reduction of 5.66% and 2.11%, in the same order. In the last period, for Chile and Mexico occurs the convergence of offshoring to return to the values reached before the crisis.

Hence, in the period before crisis, China was the region that showed the highest relocation growth rate, followed by Chile. Hereupon, if we compare China with the other countries, such as, India, Brazil, Colombia, Chile and Mexico, we notice that the growth rate is lower in 8.55 pp, 6.96 pp, 6.83 pp, 1.18 pp and 9.37 pp, respectively. Therefore, in the period under study, Mexico was the country with the smallest relocation growth. Taking into consideration the crisis interval, Colombia was the only region that revealed a positive growth rate. In its turn China, India, Brazil, Chile and Mexico presented negative growth rates that, when compared to Colombia, are inferior in 49.99 pp, 38.93 pp, 65.57 pp, 59.28 pp and 26.08 pp, in the same order. We can conclude that Brazil was the region where the crisis had the strongest impact, which, consequently, led to a decline in the relocation levels. Lastly, in the post-crisis period, India was the one with the greatest growth of relocations, followed by China. Thus, in comparison with the region with the highest rate, China, Brazil, Colombia, Chile and Mexico exhibit a lower growth in 1.3 pp, 3.36 pp, 8.64 pp, 7.53 pp and 3.98 pp, respectively. These differences show that Colombia was the country with the smallest relocation growth in this period.

Figure 1: Inter-industry relocation values between the North and the South



4 Theoretical model

This Section describes the economic set-up of the world economy composed by two countries, the North ($i = N$) and the South ($i = S$), with a fixed labor levels, L_N and L_S. The dynamic general equilibrium implies that households and firms are rational and solve their problems, free-entry R&D conditions are met, and markets clear. Infinitely-lived households inelastically supply labor, maximize utility of consumption, and invest in the firm's equity. The inputs of the aggregate good, Y, which is used for consumption and investment, are two final goods, from the North, Y_N, and from the South, Y_S. Production in S can be done by domestic firms, by firms resulting from relocations from N to S. Production in each country uses, in addition to the specific labor, a continuum of specific intermediate goods, which, in turn, are produced under monopolistic competition. In the R&D sector, each potential entrant devotes aggregate/composite final good to invent successful designs to be supplied a new monopolist intermediate-good firm/industry; i.e., R&D allows increasing the number of intermediate goods and thus the technological knowledge. As intermediate goods are country specific, some endogenous technological knowledge complements labor in N, whereas other complements labor in S.

4.1 Preferences, technology and prices

Infinitely-lived households obtain utility from the consumption of the aggregate good, C, and from the level of relocations from N to S , ℓ, because it relieves the heaviest work in the North and promotes greater professional achievement in the South, followed by higher satisfaction and better economic conditions. Households collect income from investments in financial assets (equity) and from labor. They inelastically supply labor in N, L_N, or in S, L_S. Preferences are identical across workers of both countries, $i = N, S$, and thus the world economy admits a representative household with preferences at time $t = 0$ given by

$$U = \int_0^\infty \left(\frac{(C(t) \cdot \ell^\kappa)^{1-\theta} - 1}{1-\theta} - \frac{L_i^{1+\varphi}}{1+\varphi} \right) e^{-\rho t} dt, \tag{2}$$

where κ is the sensibility of the Utility to relocations, φ is the inverse of the Frisch elasticity since consumers have disutility from work, $\rho > 0$ is the subjective discount rate, ensuring that U is bounded away from infinity, and $\theta > 0$ is the inverse of the inter-temporal elasticity of substitution, subject to the flow budget constraint

$$\dot{a}(t) = r(t) \cdot a(t) + \sum_{i=N,S} w_i(t) \cdot L_i - C(t), \tag{3}$$

where $a(t) = \sum_{i=N,S} a_i(t)$ denotes household's real financial assets/wealth holdings (composed of equity of intermediate-good producers, taking into account the profits seized by the producers), r is the real interest rate, and w_i is the wage for labor employed in the i-sector. The initial level of wealth $a(0)$ is given and the non-Ponzi games condition $\lim_{t\to\infty} e^{-\int_0^t r(s)ds} a(t) \geq 0$ is imposed. As shown in Appendix A, the representative household chooses the path of aggregate consumption $[C(t)]_{t\geq 0}$ to maximize the discounted lifetime utility, resulting in the following optimal consumption path Euler equation,

$$\frac{\dot{C}(t)}{C(t)} = \frac{1}{\theta} \cdot \left(\kappa \left(1-\theta\right) \frac{\dot{\ell}}{\ell} + r(t) - \rho \right) \Rightarrow g = \frac{1}{\theta} \cdot \left(r(t) - \rho\right), \tag{4}$$

where g is the steady-state growth rate of the consumption since in a balanced growth path $\frac{\dot{\ell}}{\ell} = 0$. Moreover, the optimal worldwide labor supply is:[4]

$$\frac{w_N}{w_S} = \left[\frac{L_N}{L_S}\right]^{\varphi}. \tag{5}$$

Furthermore, the transversality condition is also standard: $\lim_{t\to\infty} e^{-\rho t} \cdot C(t)^{-\theta} \cdot a(t) = 0$.

As proved below, in Subsection 4.3, the aggregate flow budget constraint is equivalent to the final product market equilibrium condition $Y(t) = C(t) + X(t) + Z(t)$, where Y is the

[4]In this model, there is no involuntary unemployment due to the assumption of perfectly competitive labor markets usually taken in the context of such models. However, there is voluntary unemployment, but it is undetermined in the model. Indeed, the number of hours supplied by a household $S(t)$ is a fraction u_w of the available hours of the individuals it contains, i.e., $S(t) = u_w \cdot \tilde{S}(t)$, in which $\tilde{S}(t)$ is fixed as a result of the assumption of no population growth. In this case voluntary unemployment would correspond to $(1 - u_w) \cdot \tilde{S}(t)$, which is undetermined since both u_w and $\tilde{S}(t)$ are unknown. However, apart from the recognition of the existence of voluntary unemployment, we have abstracted from the analysis of its measure because it is not the focus of our model.

composite final good, X is the total investment in intermediate-goods production and Z is the aggregate R&D expenditures. Y is produced with a CES aggregate production function for N and S:

$$Y(t) = \left[\sum_{i=N,S} \zeta_i Y_i(t)^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}, \tag{6}$$

where $i = N, S$ and thus Y_N is the output of N and Y_S is the output of S; ζ_i is the intensity parameter; and $\varepsilon \in (0, +\infty)$ is the elasticity of substitution between the both countries. All prices and wages are normalized by the price of the final good and thus are defined in real terms. Hence, we acquire $P_Y(t) = \left[\sum_{i=N,S} \zeta_i P_i(t)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}$, which in real terms is 1, and the maximization problem is given by $\max \pi_i = 1.Y - P_N Y_N - P_S Y_S$. If we accomplish the first order condition in order to the output $\frac{\partial \pi_i}{\partial Y_i}$, we get the relative price of the North:

$$\frac{P_N}{P_S} = \frac{\varsigma_N}{\varsigma_S} \left(\frac{Y_N}{Y_S} \right)^{-\frac{1}{\varepsilon}}. \tag{7}$$

Hence, the production function for N is given by

$$Y_N = \frac{L_N^{\alpha} \cdot K_N^{\beta}}{1 - \alpha - \beta} \int_0^{A_N} x_n(j)^{1-\alpha-\beta} dj, \tag{8}$$

and the production function for S is given by

$$Y_S = \frac{\left(O \cdot \ell^{-\mu} \cdot L_S \right)^{\alpha} K_S^{\beta}}{1 - \alpha - \beta} \int_0^{A_S} x_S(j)^{1-\alpha-\beta} dj, \tag{9}$$

where K_i is the human-capital index in country i and $\beta \in (0, 1)$ is the respective share in production; L_i represents the labor level of country i and $\alpha \in (0, 1)$ is the labor share in production; A_i measures the number of intermediate goods and thus evaluates the technological-knowledge level; $x_i(j)$ is the quantity of the intermediate good $j \in [0, A_i]$ and $(1 - \alpha - \beta) \in (0, 1)$ is the respective share in production. The labor level in the South, L_S, benefits from (is augment by) two corrective measures in relation to L_N, O and $\ell^{-\mu}$: O represents the positive effect induced by trade openness between countries, measured by $\frac{M_{SN} + X_{SN}}{GDP_S}$, where M_{SN} describe the imports of intermediate goods by S from N, X_{SN} describe the exports of intermediate goods by S to N, and GDP_S capture the gross domestic product of S; $\ell^{-\mu}$ measures the global impact of relocations in the Southern production and is crucial in our analysis in which ℓ evaluates the relocation levels from N to S – in line with (1) – and μ captures the sensitivity of Southern production to the relocation levels. The corrective measures should be read together as it would be incomprehensible to have relocations without trade openness and the trade openness reflects the impact of relocations. O may assume any value greater than 0, and ℓ is between 0 and 1. Depending on the Southern country, the data suggests that O and ℓ are both somewhere between 0 and 0.15, and μ assumes values between about 2.5 and 6, as we can state below. Thus, a country's relationship with abroad captured by $O{\cdot}\ell^{-\mu}$ have a positive effect on Southern labor productivity; however, per se O penalizes L_S since tends to be smaller than 1 but its increase favors L_S, whereas ℓ favors L_S since tends to be higher than 1 but its increase penalizes L_S due to the signal of the exponent.

Consequently, from (6), (8) and (9) there are substitutability between countries to achieve the world production Y and complementarity between inputs in each country to produce Y_i such that, for example, an increment of the technological knowledge in each country increase the respective marginal product of labor. The maximization problem for the two types of countries is $Max\pi_i = P_i.Y_i - w_i.L_i - \int_0^{A_i} q_i(j)x_i(j)dj$ and $q_i(j)$ is the price of the intermediate good j. Solving the problem for S we have

$$w_S = \frac{\alpha \cdot P_S \cdot Y_S}{\left(O{\cdot}\ell^{-\mu} \cdot L_S\right)} \text{ and } x_S(j) = \left[\frac{P_s \cdot \left(O{\cdot}\ell^{-\mu} \cdot L_S\right)^{\alpha} \cdot K_S^{\beta}}{q_s(j)}\right]^{\frac{1}{\alpha+\beta}}, \tag{10}$$

and then by using (9) and (10) we achieve the inverse demand functions for labor in S:

$$w_S = \frac{\alpha}{1-\alpha-\beta} P_s^{\frac{1}{\alpha+\beta}} q_s(j)^{-\left(\frac{1-\alpha-\beta}{\alpha+\beta}\right)} \left(\frac{O\ell^{-\mu}L_S}{K_S}\right)^{-\left(\frac{\beta}{\alpha+\beta}\right)}. \tag{11}$$

Similarly, for N we have

$$w_N = \frac{\alpha P_N Y_N}{L_N} \text{ and } x_N(j) = \left[\frac{P_N L_N^{\alpha} K_N^{\beta}}{q_N(j)}\right]^{\frac{1}{\alpha+\beta}}, \tag{12}$$

and bearing in mind (8) and (12):

$$w_N = \frac{\alpha}{1-\alpha-\beta} P_N^{\frac{1}{\alpha+\beta}} q_N(j)^{-\left(\frac{1-\alpha-\beta}{\alpha+\beta}\right)} \left(\frac{L_N}{K_N}\right)^{-\left(\frac{\beta}{\alpha+\beta}\right)}. \tag{13}$$

The price of the intermediate good j, $q_i(j)$, is decided in a monopolistic way. The maximization problem for both countries is given by Max $\pi_i = x_i(j).(q_i(j) - \eta)$, where η is the marginal cost, which is the same across intermediate goods and in both countries. Hence, by calculating the first order condition, $\frac{\partial \pi_i}{\partial q_i(j)} = 0, i = S, N$, it results that $q_i(j) = \frac{\eta}{1-\alpha-\beta}$. Following Acemoglu et al. (2012), from now on, we consider that $\eta = 1-\alpha-\beta$ and, consequently, $q_i(j) = q_i = 1$. As a result, from (10) and (12) we have

$$x_S = \left(P_S \left(O\ell^{-\mu} L_S\right)^{\alpha} K_S^{\beta}\right)^{\frac{1}{\alpha+\beta}} \text{ and } x_N = \left(P_N L_N^{\alpha} K_N^{\beta}\right)^{\frac{1}{\alpha+\beta}}, \tag{14}$$

which, by using (8) and (9), allows us to rewrite the production of the final-goods of both countries as:

$$Y_S = \frac{A_S}{1-\alpha-\beta}\left[P_S^{1-\alpha-\beta}(O\ell^{-\mu}L_S)^{\alpha} K_S^{\beta}\right]^{\frac{1}{\alpha+\beta}} \text{ and } Y_N = \frac{A_N}{1-\alpha-\beta}\left[P_N^{1-\alpha-\beta} L_N^{\alpha} K_N^{\beta}\right]^{\frac{1}{\alpha+\beta}}, \tag{15}$$

the wages in (11) and (13) as:

$$w_S = \frac{\alpha}{1-\alpha-\beta} P_S^{\frac{1}{\alpha+\beta}} \left(\frac{O\ell^{-\mu}L_S}{K_S}\right)^{-\left(\frac{\beta}{\alpha+\beta}\right)} \text{ and } w_N = \frac{\alpha}{1-\alpha-\beta} P_N^{\frac{1}{\alpha+\beta}} \left(\frac{L_N}{K_N}\right)^{-\left(\frac{\beta}{\alpha+\beta}\right)}, \tag{16}$$

and the profits in intermediate goods production as:

$$\pi_S = (\alpha+\beta)\left[P_S^{\frac{1}{\alpha+\beta}} (O\ell^{-\mu}L_S)^{\frac{\alpha}{\alpha+\beta}} K_S^{\frac{\beta}{\alpha+\beta}}\right] \text{ and } \pi_N = (\alpha+\beta)\left[P_N^{\frac{1}{\alpha+\beta}} L_N^{\frac{\alpha}{\alpha+\beta}} K_N^{\frac{\beta}{\alpha+\beta}}\right]. \tag{17}$$

In turn, by replacing (15) into (7), we achieve the relative price of N:

$$\frac{P_N}{P_S} = \left(\frac{\zeta_N}{\zeta_S}\right)^{\frac{\varepsilon(\alpha+\beta)}{\Theta}} \left[\left(\frac{A_N}{A_S}\right)^{\alpha+\beta} \left(\frac{L_N}{O\ell^{-\mu}.L_S}\right)^{\alpha} \left(\frac{K_N}{K_S}\right)^{\beta}\right]^{-\frac{1}{\Theta}}, \tag{18}$$

where $\Theta = 1 + (\varepsilon - 1)(\alpha + \beta)$. Moreover, from (16) and (18) results the relative wage of N, which is our measure of inter-country wage inequality:

$$\frac{w_N}{w_S} = \left[\left(\frac{\zeta_N}{\zeta_S}\right)^{-\varepsilon} \left(\frac{A_N}{A_S}\right) \left(\frac{L_N}{O\ell^{-\mu}L_S}\right)^{\frac{\alpha+\Theta\beta}{\alpha+\beta}} \left(\frac{K_N}{K_S}\right)^{\frac{\beta(1-\Theta)}{\alpha+\beta}}\right]^{-\frac{1}{\Theta}}, \tag{19}$$

and, combining (17) and (18), the relative profitability of N is:

$$\frac{\pi_N}{\pi_S} = \left(\frac{\zeta_N}{\zeta_S}\right)^{\frac{\varepsilon}{\Theta}} \left(\frac{A_N}{A_S}\right)^{-\frac{1}{\Theta}} \left[\left(\frac{L_N}{O\ell^{-\mu}L_S}\right)^{\alpha} \left(\frac{K_N}{K_S}\right)^{\beta}\right]^{\frac{\Theta-1}{(\alpha+\beta)\Theta}}. \tag{20}$$

In particular, from the expressions (18), (19) and (20), the relative price, the relative wages and the relative profitability of N decreases with a relative abundance of N-technological knowledge, $\frac{A_N}{A_S}$, North-South labor, $\frac{L_N}{L_S}$, and North-South human capital, $\frac{K_N}{K_S}$. The opposite happens when the relative abundance of South-North technological knowledge, $\frac{A_S}{A_N}$, South-North labor, $\frac{L_S}{L_N}$, global impact of relocations, $\ell^{-\mu}$, and South-North human capital, $\frac{K_S}{K_N}$, raise.

4.2 Directed technological change

4.2.1 R&D technology and technological-knowledge bias

Following Romer (1986, 1990), Lucas (1993) and Jones (1995) we now introduce horizontal-R&D activity to have endogenous growth. As a result, we can analyze how the results of the model are affected by the rate and the direction of the technological knowledge. It is assumed that in the perfectly competitive R&D sector there is free entry and each potential entrant devotes aggregate final good to produce a successful blueprint or design, which is protected by a system of patents and allows the introduction of a new intermediate-good: although the same technology can be freely available to all firms (non-rival), it can be protected by intellectual property rights such as systems of patents to prevent the imitation by other users (excludable) – e.g., Romer (1990). An innovation is revealed by the introduction of new varieties of intermediate goods inputs that complement S-labor or N-labor. The production function is given by:

$$\dot{A}_i = \lambda_i Z_i L_i^{-\gamma_{L_i}}, i \in \{N, S\} \tag{21}$$

where λ_i is the R&D productivity in N and S; Z_i is the R&D expenditure directed at discovering new intermediate goods in N and S, and the total R&D expenditures are $Z = Z_N + Z_S$; $L_i^{-\gamma_{L_i}}$ allows us to remove scale effects that are measured through labor levels. Under scale effects, $\gamma_{L_i} = 0$, it is the market size that encourages the development of technologies, whereas without scale effects, $\gamma_{L_i} = 1$, the price effect dominates the chain of effects (Acemoglu 2002). Indeed, the market-size effect can be partial removed if $0 < \gamma_{L_i} < 1$, total removed if $\gamma_{L_i} = 1$ or over counterbalance if $\gamma_{L_i} > 1$. An increase in R&D productivity and in R&D expenditures provide a boost on technological-knowledge progress.

Variable Z_i is stated through the free-entry R&D condition, which is given by $\dot{A}_i V_i = Z_i$ assuming that V_i is characterized as the market amount of a firm or the value of a patent and $\dot{A}_i$ capture the number of new inventions. Consecutively, according to the Hamilton-Jacobi-Bellman condition, the instantaneous profit is given by $\pi_i = r \cdot V_i - \dot{V}_i$, where π_i is the instantaneous profit of a single intermediate good producer in the i-country, $i = S, N$, already specified in (17) and r is the market interest rate. Using the free-entry condition and the technological-knowledge progress function and , described in (21), we have that $\dot{V}_i = 0$, as occurs, for example, in Barro and Sala-i-Martin (2014).[5] Replacing this in the Hamilton-Jacobi-Bellman condition, we obtain an expression for the real interest rate $r = \frac{\pi_i}{V_i}$. Equalizing across sectors – since interest rates is assumed to be equal across countries – leads to $\frac{V_N}{V_S} = \frac{\pi_N}{\pi_S}$. Moreover, solving for V_i in the free-entry condition taking into account (21) we have $V_i = \frac{Z_i}{\dot{A}_i} = \frac{1}{\lambda_i \cdot L_i^{-\gamma_{L_i}}}$, which dividing between countries and replacing with the previous expression we obtain $\frac{V_N}{V_S} \left(= \frac{\pi_N}{\pi_S} \right) = \frac{Z_N}{Z_S} = \frac{\lambda_N \cdot L_N^{-\gamma_{L_N}}}{\lambda_S \cdot L_S^{-\gamma_{L_S}}}$ that has the intuitive explanation: In equilibrium, the relative profitability of the N-country (LHS) must be equal to the relative cost of investing R&D resources in this country (RHS). Replacing $\frac{\pi_N}{\pi_S}$ with (20), the relative value for the technology monopolist in the N-country is:

[5] Indeed, since $\dot{A}_i V_i = Z_i$ and $\dot{A}_i = \lambda_i \cdot Z_i \cdot L_i^{-\gamma_{L_i}}$ it results that $\dot{V}_i = 0$.

$$\frac{V_N}{V_S} = \frac{\lambda_N L_N^{-\gamma_{L_N}}}{\lambda_S L_S^{-\gamma_{L_S}}} = \left(\frac{\zeta_N}{\zeta_S}\right)^{\frac{\varepsilon}{\Theta}} \left(\frac{A_N}{A_S}\right)^{-\frac{1}{\Theta}} \left[\left(\frac{L_N}{O\ell^{-\mu} L_S}\right)^{\alpha} \left(\frac{K_N}{K_S}\right)^{\beta}\right]^{\frac{\Theta-1}{(\alpha+\beta)\Theta}}, \tag{22}$$

which suggest the following the technological-knowledge bias and describe the relative productivity of N and S technologies:

$$\frac{A_N}{A_S} = \left(\frac{\zeta_N}{\zeta_S}\right)^{\varepsilon} \left(\frac{\lambda_N L_N^{-\gamma_{L_N}}}{\lambda_S L_S^{-\gamma_{L_S}}}\right)^{\Theta} \left[\left(\frac{L_N}{O\ell^{-\mu} L_S}\right)^{\alpha} \left(\frac{K_N}{K_S}\right)^{\beta}\right]^{\frac{\Theta-1}{\alpha+\beta}}. \tag{23}$$

As we show, our model is a directed technological change model (Hart 2013). The market-size channel (when the scale effects are present) or as price channel (when the scale effects are removed) are present in (23). Both effects are competitive because the price effect leads to technological-knowledge improvements that are associated with less abundant factors, while the market-size effect leads to incentives for innovations that complement the more abundant factors. Thus, in case of low substitution elasticity, the factor with less abundance dominates, which turns the price effect more powerful. However, irrespective of the elasticity of substitution among factors (excluding $\gamma_{L_i} = 1$) an increment in the relative abundance of a factor generates a technological-knowledge change biased towards that factor (Acemoglu 2002).

4.2.2 Endogenous technological-knowledge bias and inter-country wage inequality

If we replace (23) in (19), we obtain the relative return on N-labor, which is the inter-country wage inequality measure from the demand side:

$$\frac{w_N}{w_S} = \left[\left(\frac{\lambda_N}{\lambda_S}\right) \left(\frac{L_N^{-\gamma_{L_N}}}{L_S^{-\gamma_{L_S}}}\right) \left(\frac{L_N}{O\ell^{-\mu} L_S}\right)\right]^{-1}, \tag{24}$$

which, combined with the labor-supply perspective in (5), gives rise to the following expression for inter-country wage inequality:

$$\frac{w_N}{w_S} = \left[\left(\frac{\lambda_N}{\lambda_S}\right) \left(\frac{L_N^{-\gamma_{L_N}}}{L_S^{-\gamma_{L_S}}}\right) \left(\frac{1}{O\ell^{-\mu}}\right)\right]^{-\frac{\varphi}{\varphi+1}}. \tag{25}$$

Analyzing the effects of each variable we can consider that an increase (decrease) in $\frac{\lambda_N}{\lambda_S}$ induces a decrease (increase) in $\frac{w_N}{w_S}$, and an increase (decrease) in $\frac{L_N}{O\ell^{-\mu}L_S}$generate a different impacts on wages because we need to take into account the distinct possibilities of scale effects. Admitting the particular case $\gamma_{L_N} = \gamma_{L_S}$, for example, we can conclude that if the variation across the scale effects it is smaller (higher) then, the variation among the relative return on North-labor will be higher (smaller) and, consequently, there will be an increase (decrease) on wage inequality. In turn, if the variation across the scale effects is one, there will be no consequences on the relative return on North-labor and on the wage inequality.

4.2.3 Endogenous technological knowledge and economic growth

First, it is crucial to take into account the relation of the relative price of N in (18) and replace it in (23), which give us $\frac{P_N}{P_S} = \left(\frac{\lambda_N L_N^{-\gamma_{L_N}}}{\lambda_S L_S^{-\gamma_{L_S}}}\right)^{-(\alpha+\beta)} \left(\frac{L_N}{O\ell^{-\mu}L_S}\right)^{-\alpha} \left(\frac{K_N}{K_S}\right)^{-\beta}$. Moreover, considering the real price of Y, $P_Y(t) = \left[\sum_{i=N,S} \zeta_i P_i(t)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} = 1$, we obtain $\frac{P_N}{P_S} = \left(\frac{1}{\zeta_N^{\varepsilon} P_S^{1-\varepsilon}} - \frac{\zeta_S^{\varepsilon}}{\zeta_N^{\varepsilon}}\right)^{\frac{1}{1-\varepsilon}}$. Thereby, using both equations, we have:

$$P_S = \left[\left(\frac{\lambda_N L_N^{-\gamma_{L_N}}}{\lambda_S L_S^{-\gamma_{L_S}}}\right)^{-(\alpha+\beta)(1-\varepsilon)} \left(\frac{L_N}{O\ell^{-\mu}L_S}\right)^{-\alpha(1-\varepsilon)} \left(\frac{K_N}{K_S}\right)^{-\beta(1-\varepsilon)} \zeta_N^{\varepsilon} + \zeta_S^{\varepsilon}\right]^{\frac{1}{\varepsilon-1}}. \tag{26}$$

Furthermore, applying the $r = \frac{\pi_i}{V_i}$ and $V_i = \frac{1}{\lambda_i L_i^{-\gamma_{L_i}}}$, as we already established above, and substitute all the expressions on the the market interest rate equation, we have:

$$r_S = (\alpha+\beta) P_S^{\frac{1}{\alpha+\beta}} \left(O\ell^{-\mu}L_S\right)^{\frac{\alpha}{\alpha+\beta}} K_S^{\frac{\beta}{\alpha+\beta}} \lambda_S L_S^{-\gamma_{L_S}}, \tag{27}$$

Finally, using the Euler equation from the consumer problem (4), we obtain the economic growth rate:

$$g = \frac{1}{\theta}(r-\rho), \tag{28}$$

where r is given by (27) bearing in mind (26). Through the equation above, we can conclude that both the rate time of preference and the elasticity of marginal utility of consumption affects negatively the economic growth rate, instead of a higher R&D productivity and human-capital index that can be translate into positive impacts on economic growth rate under $\varepsilon > 1$ (North and South countries as substitutes in final goods production). Secondly, as we saw earlier, the labor levels provide different actions on economic growth and we need to take into account the distinct possibilities of scale effects under $\varepsilon > 1$: if $\gamma_{L_i} = 0$, which means there are only market-size effects, the economic growth is positively affected by labor levels; if $0 < \gamma_{L_i} < 1$, where the scale effects are partially removed, labor levels can have positive impacts, but smaller than if $\gamma_{L_i} = 0$; if $\gamma_{L_i} = 1$, which means that we only have present price effects, and the impacts felt on the economic growth rate are marginal effects; and if $\gamma_{L_i} > 1$, the market effects are counterbalance and the outcome on growth are negative.

Moreover, bearing in mind the utility function, U, in (2), we can examine the welfare, W_C, along the balanced growth path, which is given by the following equation – see Appendix B:

$$W_C = \frac{1}{1-\theta}\left\{\frac{\left(C(0)\cdot \ell(0)^{\kappa}\right)^{1-\theta}}{\left[\rho - g\left(1-\theta\right)\right]} - \frac{1}{\rho}\right\} - \frac{L_i^{1+\varphi}}{\left(1+\varphi\right)\rho}, \tag{29}$$

where $C(0) = \left(\frac{\ell^{\kappa(1-\theta)}-1}{\ell^{\kappa(1-\theta)}}\right)^{\frac{1}{1-\theta}}$, $\ell(0)$ and κ are, respectively, the consumption and relocation levels at time 0 and the relocation sensitivity to consumption.[6] In order to highlight the different impacts of the relocations on the welfare, we analyze the first derivative of the expression (29) with respect to the relocations:

$$\frac{\partial W_C}{\partial \ell} = \underbrace{\frac{\kappa\cdot \ell^{\kappa(1-\theta)-1}}{\rho - g\left(1-\theta\right)}}_{>0} + \underbrace{\frac{\left[\ell^{\kappa(1-\theta)}-1\right]}{\left[\rho - g\left(1-\theta\right)\right]^2}}_{<0}\cdot \underbrace{\frac{\partial g}{\partial \ell}}_{<0} > 0, \tag{30}$$

i.e., for reasonable (the usual ones in the literature and in the data) parameter values the sign of the derivative $\frac{\partial W_C}{\partial \ell}$ is unequivocally positive.

[6] Bearing in mind the expression for $C(0)$, the welfare measure can be write as $W_C = \frac{1}{1-\theta}\left\{\frac{\ell^{\kappa(1-\theta)}-1}{[\rho-g(1-\theta)]} - \frac{1}{\rho}\right\} - \frac{L_i^{1+\varphi}}{(1+\varphi)\rho}$.

4.3 Macroeconomic aggregation

To analyze the consistence of our general-equilibrium endogenous growth model, we now show that the aggregate final good, Y, is used in consumption, C, and investment, $X + Z$; firms and households are rational and solve their problems; free-entry R&D conditions are met; and markets clear.

The households budget constraint is given by equation (3). From the analysis in Subsection 4.2.1, we know that the real financial assets of households, $a = \sum_{i=N,S} a_i$, is given by the sum of $a_N(t) = A_N V_N = \int_0^{A_N(t)} V_N(j,t) \cdot dj$ with $a_S = A_S V_N = \int_0^{A_N(t)} V_N(j,t) \cdot dj$, where a_N and a_S are the market value of all the firms that produce intermediate goods at time t in N and S, respectively. Hence, the change in assets is $\dot{a}_i = \dot{A}_i V_i + A_i \dot{V}_i$, but since $\dot{A}_i V_i = Z_i$ and $\dot{A}_i = \lambda_i \cdot Z_i \cdot L_i^{-\gamma_{L_i}}$ we have that $\dot{V}_i = 0$ whereby $\dot{a}_i = \dot{A}_i V_i = Z_i$ and $\dot{a}(t) = \sum_{i=N,S} \dot{a}_i(t) = \sum_{i=N,S} Z_i(t) = Z(t)$. In turn, with this information in mind, from the Hamilton-Jacobi-Bellman condition we have that $\pi_i = r \cdot V_i$ and thus $\pi_i \cdot A_i = r \cdot a_i$, where π_i is given by (17); as a result, $r(t) \cdot a(t) = r(t) \cdot \sum_{i=N,S} a_i(t) = \sum_{i=N,S} \pi_i(t) \cdot A_i(t) = \sum_{i=N,S} \pi_i(t) \cdot A_i(t) = \frac{(\alpha+\beta)(1-\alpha)}{1+\alpha+\beta} Y$. Moreover, from (10) and (12) we have that $\sum_{i=N,S} w_i(t) \cdot L_i = \alpha Y$. Hence, it follows that the households' budget constraint in (3) becomes

$$\overbrace{\underbrace{\dot{a}}_{}}^{Z} = \overbrace{\underbrace{r \cdot a}_{}}^{\frac{(\alpha+\beta)(1-\alpha)}{1+\alpha+\beta} Y} + \overbrace{\underbrace{\sum_{i=N,S} w_i(t) \cdot L_i}_{}}^{\alpha Y} - \overbrace{\underbrace{C}_{}}^{C} \Rightarrow Y = C + X + Z$$

where we used the condition $X = \sum_{i=N,S} A_i x_i = \frac{1-\alpha}{1+\alpha+\beta} Y$ from equations (14) and (15). This condition states that, at every point in time, GDP, Y, must be allocated to consumption, C, the production of intermediates, X, and the creation of new goods, Z.

5 Quantitative results

In this Section, we start by quantifying the inter-country wage inequalities, (24), measured by $\frac{w_N}{w_S}$, according to the relocation levels, ℓ, taking into account different sensitivities of Southern production at the reallocation levels, μ,and scale effects, $\gamma = \gamma_{L_N} = \gamma_{L_N}$. After that, we will evaluate how the wage inequality based on (24) and economic growth in (28), g, react to different values of (i) relocation sensitivity, μ, and (ii) scale effects. Lastly, we will analyze how the welfare in (29), W_C, behaves, considering the measurement of inter-industry relocation in (1), S_i^B, the real economic growth rate between the N (the US) and each S-country in (31), g and, L_i as an average between North and South.

5.1 Calibration and data

For the quantitative results, we need to calibrate several parameters such as α (the labor share in production), β (the human-capital share in production), μ (the relocations sensitivity), ζ_N and ζ_S (the intensity of the production of each country), ε (the elasticity of substitution between countries), γ (scale effects), θ (the inverse of the inter-temporal elasticity), ρ (the rate time of preference) and k (relocation sensitivity to consumption). Furthermore, it is necessary to find values for the exogenous variables: L_N and L_S (measured by the number of persons engaged in the labor market in North and South, respectively); K_N and K_S (figured by the human-capital index in North and South); O (calculated through trade openness between countries); λ_N and λ_S (measured by the productivity of R&D activities in North and South, respectively); w_N and w_S (corresponds, respectively, to the annual average wages per employee in North and South countries); g (the economic growth rate between the North and South country) and W_c (the social welfare among North and South region).

Most of the parameters' values were chosen according the literature. Hence, to calibrate the share of labor, we adopt the standard values followed by Jones et al. (1993), $\alpha = 0.64$. For the share of human capital, we consider the values determined in the literature by Gómez (2005) where $\beta = 0.36$. The value for the inter-temporal elasticity θ was chosen based on the estimations performed by Kula (2004), Evans (2005) and Lopez (2008). We decided to collect the values obtained for the elasticity of each country, Brazil, Chile, Colombia, India, the US and Mexico and, then, we obtained an average and attained $\theta = 1.54$. For the elasticity of substitution between countries, ε, and the intensity of North, ζ_N, and South production, ζ_S, we follow, the values adopted by Dinopoulos and Segerstrom (2006), where $\varepsilon = 1.5$, $\zeta_N = 1$ and $\zeta_S = 3.5$. The values assumed for scale effects will be $\gamma = \gamma_{L_N} = \gamma_{L_N} = 0$, $\gamma = \gamma_{L_N} = \gamma_{L_N} = 0.5$ and $\gamma = \gamma_{L_N} = \gamma_{L_N} = 1$. To calibrate the remaining parameters relocation sensitivity, μ, disposed of in (24), and in (28), and the relocation sensitivity to consumption, k, stated in (29), we decided to estimate them using the simultaneous equation model, since both are not considered in the literature. To mitigate the endogeneity, a function was considered to describes offshoring, relating the wage inequality, $\frac{w_N}{w_S}$, and trade openness, O,as defined in equation *(a)*. The four equations used are then defined in the following system – (*a*), (*b*) from (25), (*c*) from (26)-(28), and (*d*) from (29).

$$\begin{cases} \ell_t = \phi_0 + \phi_1 ln\left(\frac{w_{N_t}}{w_{S_t}}\right) + \phi_2 O_t + \varepsilon_{1t} & (a) \\ \frac{w_{N_t}}{w_{St}} = \left[\left(\frac{\lambda_{N_t}}{\lambda_{S_t}}\right)\left(\frac{L_{N_t}^{-\gamma_{L_N}}}{L_{S_t}^{-\gamma_{L_S}}}\right)\left(\frac{1}{O_t \ell_t^{-\mu w}}\right)\right]^{-\frac{1}{2}} + \varepsilon_{2t} & (b) \\ g_t = 0.65\left\{\left[\left(\frac{\lambda_{N_t} L_{N_t}^{-\gamma_{L_N}}}{\lambda_{S_t} L_{S_t}^{-\gamma_{L_S}}}\right)^{0.5}\left(\frac{L_{N_t}}{O_t \ell_t{}^{-\mu} L_{S_t}}\right)^{0.32}\left(\frac{K_{N_t}}{K_{S_t}}\right)^{0.18} + 6.5\right]^2 \left(O_t \ell_t{}^{-\mu} L_{S_t}\right)^{0.64} K_{S_t}^{0.36} \lambda_{S_t} L_{S_t}^{-\gamma_{L_S}} - 0.015\right\} + \varepsilon_{3t} & (c) \\ W_{C_t} = -1.85\left[\frac{\ell_t^{-0.54k} - 1}{0.015 + 0.54 g_t} - \left(\frac{1}{0.015}\right)\right] + \frac{L_{i,t}^2}{0.03} + \varepsilon_{4t} & (d) \end{cases}$$

with $t = 1, 2, ..., 18$. The estimations produced are exhibited in Appendix D.

Concerning the variables used in our model, we decided to collect yearly data for the N (the US) and S-countries (Brazil, Chile, Colombia, India and Mexico) between 2000 and 2017. Variable linked with the labor level provided by N and S, L_N and L_S, were measured by the number of persons engaged in the labor market and the variable characterized as the human-capital index, K_N and K_S, were collected from the Penn World Table (version 9.1). The productivity of R&D activities in N, λ_N, and S, λ_S, was measured by the total patent grants held by residents and non-residents in each country and acquired from the World Intellectual Property Organization (WIPO). The values of these variables L_i and λ_i were normalized by dividing them by the population in the country. To calculate the trade openness, O, it was necessary to obtain data from the World Integrated Trade Solution (WITS) for the imports and exports of intermediate goods carried out between N and S, and collected data from the World Bank database for the Gross Domestic Product (GDP) of each South country. Regarding the annual average wages, $\frac{w_N}{w_S}$, data was collected from the Organization for Economic Co-operation and Development (OECD) database for Chile, Mexico and the US, from the CEIC (https://www.ceicdata.com/en) for China and India and about the annual wages for Brazil and Colombia we used the monthly earnings indicator provided from the International Labor Organization database (ILOSTAT). Considering the economic growth, $g(t)$,and social welfare, $W_C(t)$, the proxies used were, respectively,

$$g(t) = \frac{(GDPGrowthRate(t))_N GDP_N(t) + (GDPGrowthRate(t))_S GDP_S(t)}{GDP_N(t) + GDP_S(t)} \tag{31}$$

and

$$W_C(t) = \frac{HFC(Annual\% + HFC(Annual\%Growth(t))_S GDPpercapita_S(t)}{GDPpercapita_N(t) + GDPpercapita_S(t)} \tag{32}$$

where HFC is the Households and NPISHs Final consumption expenditure (annual % growth) and the data were attained from the World Bank databases. For the countries such as India, Brazil and Colombia, it was not possible to obtain all data in the period 2000 to 2017 to construct Subsections 5.2 and 5.3. Thus, the results provided for India will be calculated for 2003 to 2017. Relatively to Brazil will be developed for 2001-2002, 2005-2009 and 2011-2017. The results produced for Colombia will be figured for 2002-2007 and 2010-2017.

Table 1: Parameter values and exogenous variables

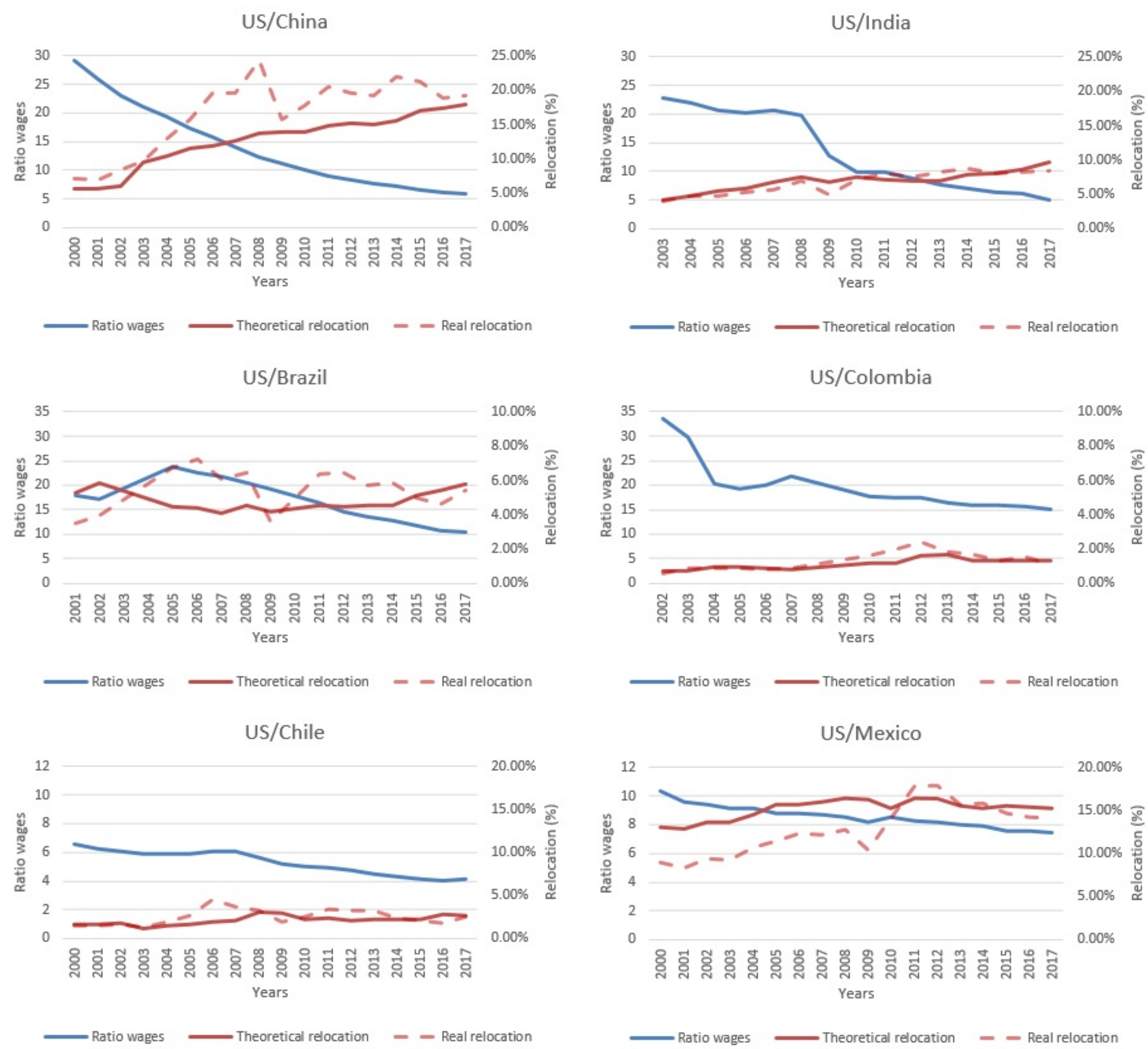
Parameter / Variable	Description	Source
$\varphi = 1$	Inverse of the Frisch elasticity	Afonso and Lima (2020)
$\alpha = 0.64$	Labor share in production	Jones et al. (1993)
$\beta = 0.36$	Human-capital share	Gómez (2005)
$\widehat{\mu}_{China} = 5.8178$, $\widehat{\mu}_{India} = 5.3470$ $\widehat{\mu}_{Brazil} = 4.5860$ $\widehat{\mu}_{Colombia} = 3.0711$ $\widehat{\mu}_{Chile} = 2.4794$ $\widehat{\mu}_{Mexico} = 5.0053$	Relocations sensitivity	Estimated
$\varepsilon = 1.5$	Elasticity of substitution between countries	Dinopoulos and Segerstrom (2006)
$\zeta_N = 1$	Intensity of the North production	Dinopoulos and Segerstrom (2006)
$\zeta_S = 3.5$	Intensity of the South production	Dinopoulos and Segerstrom (2006)
$\rho = 0.015$	Rate time of preference	Acemoglu, Aghion, Bursztyn, and Hemous (2012)
$\theta = 1.54$	Inverse of the inter-temporal elasticity	Kula (2004), Evans (2005), Lopez (2008)
$\gamma_L = 0, \gamma_L = 0.5, \gamma_L = 1$	Scale effects	Assumed
$\widehat{\kappa}_{China} = 0.9357$ $\widehat{\kappa}_{India} = 0.3889$ $\widehat{\kappa}_{Brazil} = 0.1435$ $\widehat{\kappa}_{Colombia} = 0.4146$ $\widehat{\kappa}_{Chile} = 0.0716$ $\widehat{\kappa}_{Mexico} = 0.0301$	Relocation sensitivity to consumption	Estimated

5.2 Theoretical measure of relocations and inter-country wage inequality

To determine the theoretical relocation measure for each pair of countries and year we use (24), the real values for $\frac{w_N}{w_S}$, $\frac{\lambda_N}{\lambda_S}$, $\frac{L_N}{L_S}$, and the calculated values for the trade openness, using $O = \frac{M_{SN}+X_{SN}}{GDP_S}$. Finally, we estimate, based on (24), the relocation sensitivity, $\hat{\mu}$, for each pair of countries (the US *vs* one South country) and, consequently, we estimate the theoretical relocation measure, according to different values of scale effects, $\gamma_L = 0, \gamma_L = 0.5, \gamma_L = 1$ – see Appendix D. Through this procedure, we can compare the real – see Section 3 – and theoretical values for relocations – see Figures 2, 3 and 4. In each subFigure, the solid blue line represents the wage ratio between the North, the US, and each South country, the solid red line is characterized as the theoretical relocation measure, and the dashed line expresses the effective relocation measure, S_i^B

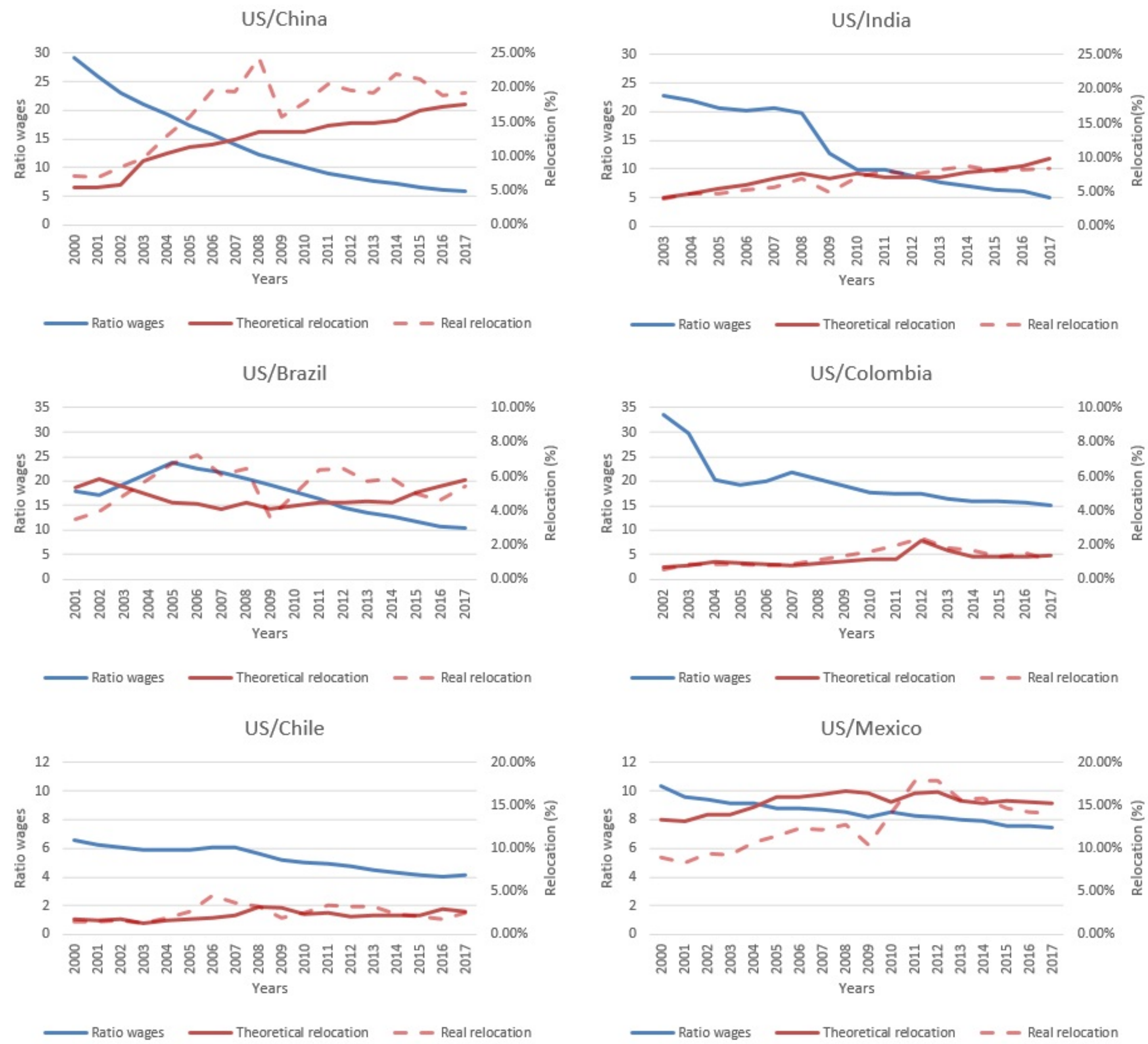
– see Section 3. Furthermore, we will analyze how inter-country wage inequality, $\frac{w_N}{w_S}$, behaves according to different values of relocation sensitivity, μ, and considering the presence, $\gamma_L = 0, \gamma_L = 0.5$, and the absence, $\gamma_L = 1$, of scale effects. The range of values selected for the relocation sensitivity of each pair of countries will be within two standard deviations of the mean.

Figure 2: Wage inequality and relocations when $\gamma_L = 0$ and $\widehat{\mu}_{China} = 5.8178$, $\widehat{\mu}_{India} = 5.3470$, $\widehat{\mu}_{Brazil} = 4.5860$, $\widehat{\mu}_{Colombia} = 3.0711$, $\widehat{\mu}_{Chile} = 2.4794$ and $\hat{\mu}_{Mexico} = 5.0053$



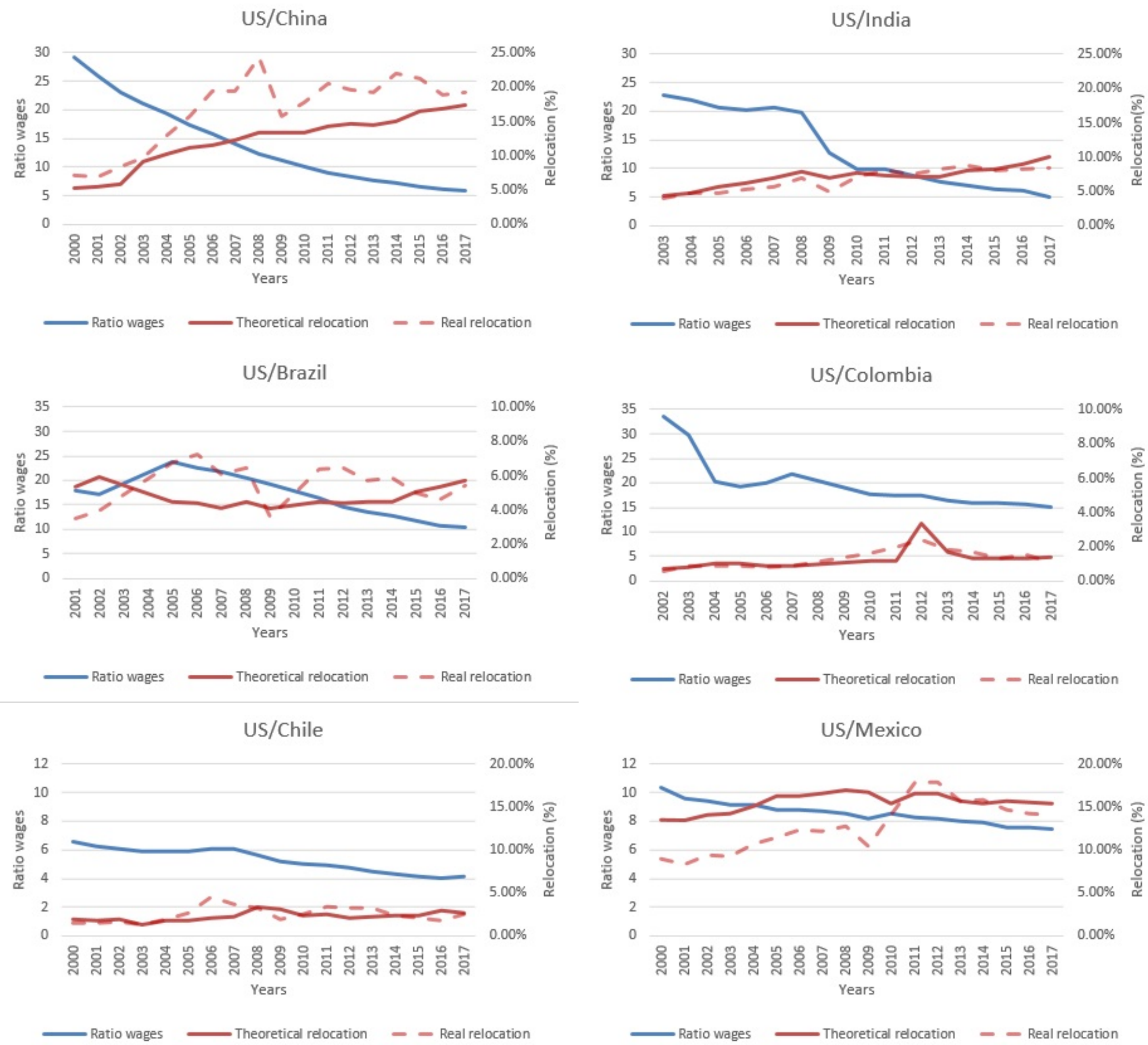
Under scale effects and when $\gamma_L = 0$ is visible an increase of relocation values in all countries and over the years, meaning that throughout the 2000s there has been an increase in the production of intermediate goods in South (Brazil, China, Chile, Colombia, India and Mexico) that are then exported to the North – see Figure 2. If we analyze each subFigure, we observe that relocations between the US and China raise about 12.30 pp in seventeen years. In 2000 the values were around to 5.55% while in 2017 they were about 17.85%. The same occurred for India that reveled a higher growth in values. In 2003, relocation values were around 4.15% and in 2017 these values increased to 9.73%. The remaining countries did not experience substantial differences in this range of years, but we notice improvements. For Brazil, the results were about 5.29% in 2001 and reached 5.80% in 2017. For Colombia, the results were 0.70 in 2002 and achieved to 1.35% in 2017. In 2000 Chile got 1.66% and in 2017 obtained 2.62%. Mexico also showed slight growth, presenting values of 13.06% in 2000 and 15.24% in 2017, and after China exhibited the highest reallocation levels.

Figure 3: Wage inequality and relocations when $\gamma_L = 0.5$ and $\widehat{\mu}_{China} = 5.8178$, $\widehat{\mu}_{India} = 5.3470$, $\widehat{\mu}_{Brazil} = 4.5860$, $\widehat{\mu}_{Colombia} = 3.0711$, $\widehat{\mu}_{Chile} = 2.4794$ and $\hat{\mu}_{Mexico} = 5.0053$



The results found in Figure 3 for $\gamma_L = 0.5$ are similar to the ones in Figure 2. According to the calculations performed, relocations have increased in all the countries concerned, particularly in China and India. The results obtained for relocations in 2000 and 2003 were around 5.45% and 4.21%, respectively. In 2017, the values reached about 17.56% and 9.88% for China and India, respectively. The differences were not so noticeable for Brazil, Colombia, Chile and Mexico, but there were also improvements. The Brazil estimates were 5.32% in 2001, 0.72% for Colombia in 2002, and 1.77% for Chile in 2000. According to the same order, these countries achieved 5.77%, 1.36% and 2.66% in 2017. Mexico was, again, one of the regions that revealed the highest rates of relocation. However, it presented the smallest gains in percentage terms, obtaining values of 13.30% in 2000 and 15.32% in 2017.

Figure 4: Wage inequality and relocations when $\gamma_L = 1$ and $\widehat{\mu}_{China} = 5.8178$, $\widehat{\mu}_{India} = 5.3470$, $\widehat{\mu}_{Brazil} = 4.5860$, $\widehat{\mu}_{Colombia} = 3.0711$, $\widehat{\mu}_{Chile} = 2.4794$ and $\hat{\mu}_{Mexico} = 5.0053$



In Figure 4 we proceed similarly, but by removing scale effects, $\gamma_L = 1$. The values for relocations are very similar to those obtained previously in Figures 2 and 3. The countries that exhibit the considerable increase over the years were, once again, China and India. In these South countries, relocations results were around 5.35% and 4.26% in the first year under analyzes, and 17.28% and 10.04% in 2017, respectively. To Brazil, the numbers obtained between 2002 and 2017 showed an increase of fewer than 0.5 pp, whereas in the first year of study the values of this type of relocation reached 5.35%, and in the last year they acquired 5.74%. For Colombia and Chile, the percentage differences between the initial and the final year were not considerable, such as Brazil. For Colombia the relocation values were about 0.74% in 2002, and 1.88% for Chile in 2000. In 2017, were around 1.36% for Colombia and 2.71% for Chile. In turn, Mexico showed, a small growth between the initial and the final year, when compared to China and India. In 2000 this country achieved 13.54% and in 2017 reached 15.40%.

Bearing in mind Figures 2, 3 and 4, we conclude that relocation values have increased over time in all countries. In other words, the production of intermediate goods in South countries that are then exported to the North country has grown significantly. As the scale effects, given by $\gamma_L = 0, \gamma_L = 0.5$ and $\gamma_L = 1$, rise we observe that there are a few small positive and negative changes in some regions. On the one hand, in China we observed that the values obtained are lower as the effects of scale increase, reaching their smallest results when the scale effects are 1. On the other hand, for countries such as, India, Brazil, Colombia, Chile and Mexico an enhance of scale effects has the opposite repercussion. That is, as the value of this parameter increases, the relocation results also rise over time. Nevertheless, regardless of the scale effects, the regions that reveal the largest variation in relocations over time are China and India. In turn, Mexico, despite being a region with a lower growth rate of relocations over the years, is the country that, after China, exhibited the most significant quantities of intermediate goods exported to the North, with relocation values nearby 13%.

Comparing the values estimated based on the empirical methodology in Section 3 with the theoretical values now presented, we observe that in both measures the values are similar for countries such as India, Brazil, Colombia, Chile and even Mexico. However, for China the similarities are not evident. Moreover, we observe that theoretical values reach lower values when compared to the results obtained through the methodology in Section 3. It should also be emphasized that the paths are similar, suggesting that both measures well captured evolution.

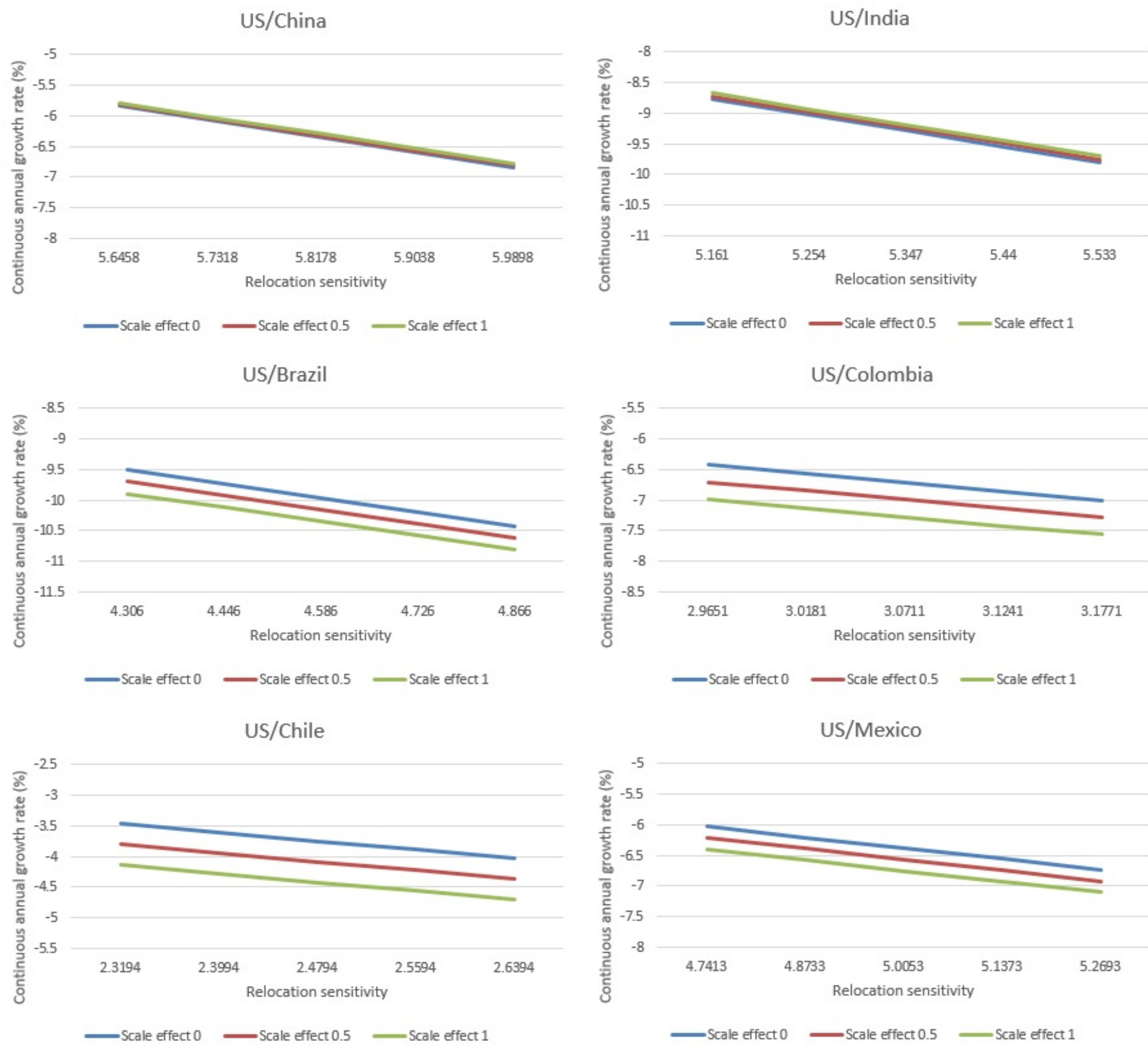
With regard to the relative return of North labor, which is a measure of inter-country wage inequality, the significant decrease in inequality is visible in all countries. This pattern has been concomitant with the increase in relocations and thus we can state that relocations promote a decrease of inter-country wage inequality. To capture this wage disparity behavior, between the North and the South, $\frac{w_N}{w_S}$, according to different values of relocation sensitivity and scale effects, we decided to develop Figures that exhibit the continuous annual growth rate of the dependent variable – see Figure 5. We started by using the wage inequality function (24), considering the measurement of inter-industry relocation S_i^B in (1), and a range of values for the relocation sensitivity that will be within two standard deviations of the mean, as stated previously. Thus, for China, India, Brazil, Colombia, Chile and Mexico, the scale will fluctuate between $[5.6458, 5.9898]$, $[5.1610, 5.5330]$, $[4.306, 4.866]$, $[2.9651, 3.1771]$, $[2.3194, 2.6394]$ and $[4.7413; 5.2693]$, respectively. Therefore, when we analyze the subFigures, we concluded that, regardless of the presence of a *market-size effect* or a *price effect*, the inter-country wage inequality between the first and last year decreases considerably as the relocation sensitivity increases. As the scale effect value rises, there is a slight boost in the continuous annual growth rate for all pairs of regions, except for China and India.

Through Figure 5 we observe that the pair of regions with the highest continuous annual growth rate – in other words, the couple of countries with the greatest decrease in wage inequality – when the scale effect value is 0, $\gamma_L = 0$, and the relocation sensitivity is higher is Brazil, followed by India. In this sense, both countries achieve values close to -10.42% and -9.80%, respectively. Less successful, Chile and Mexico are the countries that exhibit the lowest continuous annual growth rate when the parameter under analyzes enhances, reaching rates around -4.03% and -6.73%, according to the same order. China and Colombia and Mexico, attain values nearby -6.84% and -7.00%, respectively. In turn, when the scale effect is 0.5, $\gamma_L = 0.5$,the countries that achieve higher results when the relocation sensitivity reaches its maximum value are, again, Brazil and India, with -10.61% and -9.75%, according to the same order. China and Chile are the countries that illustrate the lowest continuous annual growth rate with values around -6.81% and -4.36%, respectively. Moreover, Colombia acquires rates close by -7.28% and Mexico approximately -6.92%. When the scale effect is 1, $\gamma_L = 1$, Brazil and India are, one more time, the countries with the greatest results, obtaining values around -10.81% and -9.70%, considering the particular order. Countries such as China and Chile, present the lowest rates, with -6.78% and -4.70%, respectively. Colombia reach values around -7.56% and Mexico nearby -7.10%.

Regarding the annual growth rate variations achieved by each pair or North-South countries, as the relocation sensitivity improves, we perceive that these fluctuations are the same, whether in the presence or absence of scale effects. Thus, one the one hand, the couple of countries with the giant oscillations, as the relocation sensitivity boosts, is India, followed by China, acquiring values around -1.03 pp and -0.99 pp, considering the respective order. On the other hand, the set of countries with the smallest variations are Chile and Colombia, reaching values close by -0.56 pp and -0.58 pp, respectively. Brazil and Mexico, according to the same order, attain fluctuations nearby -0.91 pp and -0.70 pp.

In addition, as expected, China and India are the countries in which an increase in relocation sensitivity has a considerable impact on wage inequality. This occurs due to the significant relocation activity growth over the years. In turn, Colombia and Chile exhibit a slight decrease in the wage disparity as the parameter rises, as predicted, since both reveal a small relocation level when compared to the others countries.

Figure 5: Continuous annual growth rate of wage inequality, $\frac{w_N}{w_S}$ between the first and the last year under analysis, according to different relocation sensitivities, μ, and scale effects, γ_L



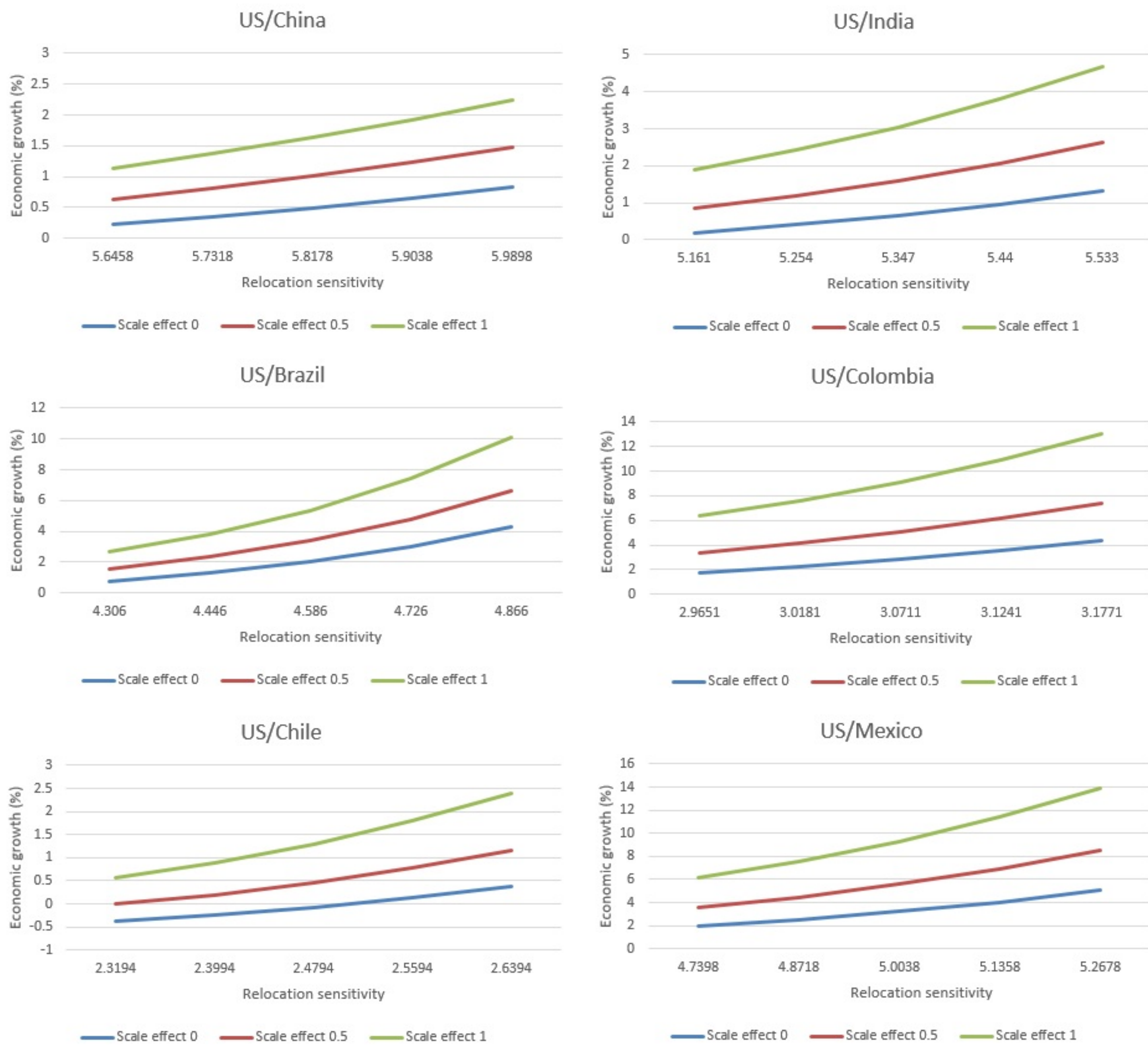
5.3 Relocations and economic growth

Our goal in this Subsection is to evaluate how the average of economic growth in (28), g, of each pair of countries, reacts in conformity with a range of values for the relocation sensitivity, as identified earlier in Subsection 5.2, and according to different scale effects, $\gamma_L = 0$, $\gamma_L = 0.5$ and $\gamma_L = 1$, for the period 2000 to 2017. To achieve these results, we will consider the parameters exhibited in Table 1, the data available for the variables and we will consider the measurement of inter-industry relocation S_i^B in (1).

According to Figure 6, regardless of the scale effects, the economic growth rate of each pair of countries increases at the pace of the relocation sensitivity, μ. However, a bigger improvement in the growth rate is visible as the value of scale effects raises. In other words, with the same relocation sensitivity, μ, it is possible to achieve greater economic growth if the scale effect value is higher for all regions. When the effects of scale are 0, $\gamma_L = 0$,the countries with the most substantial increase in economic growth as the relocation sensitivity boosts are Brazil with a variation close by 3.52 pp, Mexico around 3.14 pp, and Colombia with a variation about 2.56 pp. The countries that exhibit a less growth, given the presence of the scale effect and according to the range of the sensitivity, are China, Chile and India in which the fluctuations do not exceed 0.60 pp, 0.73 pp, and 1.12 pp, respectively. When the value of the scale effects is 0.5, $\gamma_L = 0.5$, and if we compare the initial value of the parameter with the final one, we observe that Brazil, Mexico and Colombia are, once again, the countries that present the major improvement in economic growth with variations close by 5.12 pp, 4.94 pp and 4.03 pp, respectively. Less successful, China, Chile and India are the countries with the lowest growth, reaching fluctuations around 0.84 pp, 1.16 pp, and 1.77 pp, according to the same order. Lastly, when the scale effects are removed, $\gamma_L = 1$, we notice a sharp rise in fluctuations of economic growth when compared to the presence of the effects of scale. Therefore, the variation for Mexico is around 7.77 pp, for Brazil is about 7.46 pp, and for Colombia is close to 6.68 pp. For regions as China, Chile and India the fluctuations are no more than 1.11 pp, 1.85 pp, and 2.78 pp, respectively.

The obtained results show, as already mentioned, that as the relocation sensitivity and the value of scale effects increase the improvements in economic growth are more significant, particularly in Brazil and Mexico. As detected in Figure 1, Brazil is a region where the relocation activity has not revealed significant growth over the years. In this sense, everything indicates that this country may be more interested in the specialization of final commodities, instead of intermediate goods. Thus, this considerable impact on economic growth caused by an increase in the relocation sensitivity reveals that, if this region invested more in the production of intermediate goods, the repercussions would be significantly positive. With regard to Mexico, this country reveals a range of values relative to the relocation sensitivity similar to China and India. However,

Figure 6: Average economic growth values, according to different relocation sensitivities, μ, and scale effects, γ_L



in the case of the region under analysis, a rise in the relocation sensitivity provoke a higher and positive impact on economic growth due to the giant connection with the US. For Colombia, the enhancement in economic growth is also substantial, as the parameter value boosts. As we perceive throughout this research, this country exhibits low relocation levels, which means that a slight increase in the relocation sensitivity will lead to considerable gains in the dependent variable. The opposite occurs for Chile, where a rise in sensitivity does not reveal a significant impact on economic growth when compared to the other countries.

To conclude, for China and India we observed that the fluctuations of the variable are similar, regardless of the presence or absence of the scale effects. In this sense, as predicable, the economic growth changes in these countries is not extremely substantial since their relocation activities are already highly developed. Thus, a significant improvement in the relocation sensitivity parameter would be necessary for the variable g to increase remarkably.

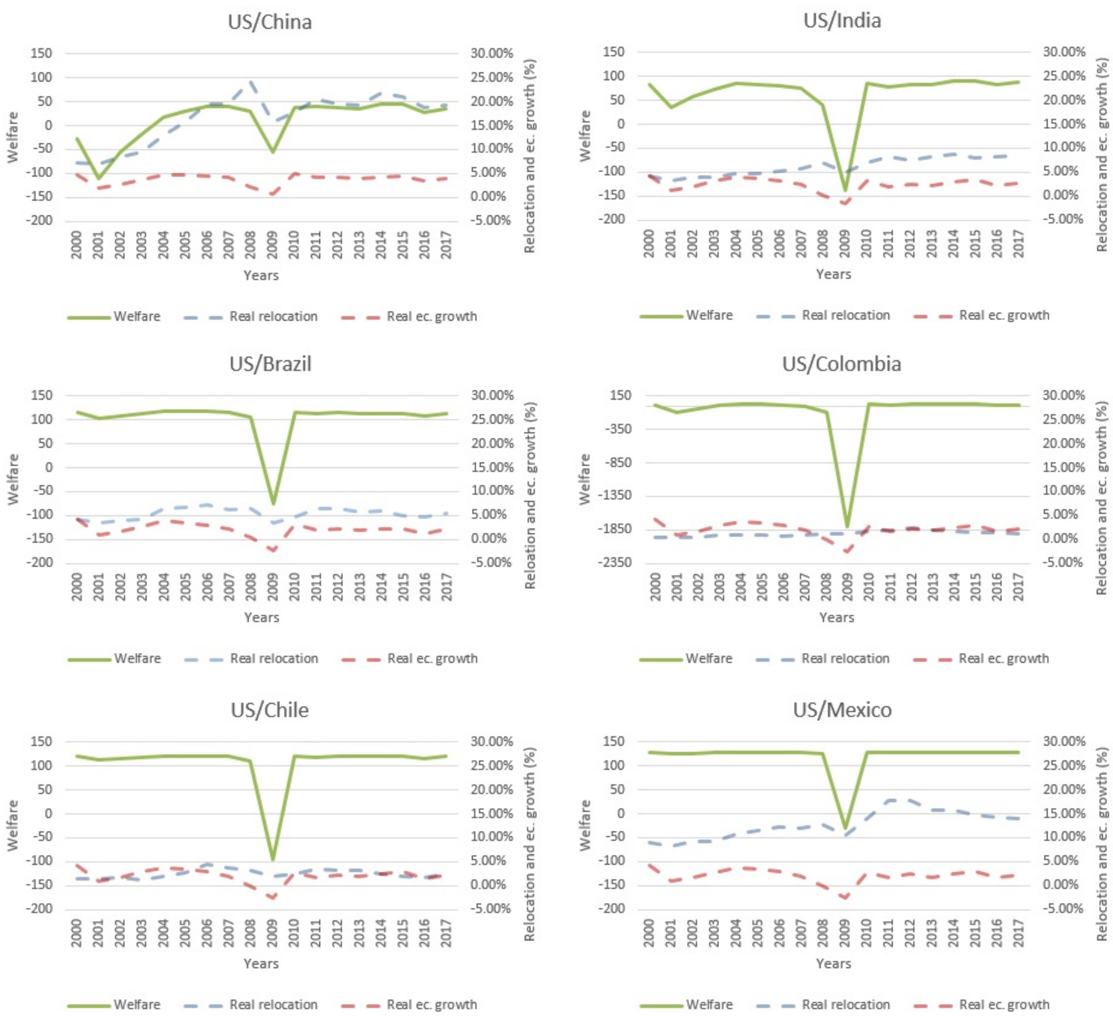
5.4 Relocations and welfare

In this Subsection our goal is to describe the welfare behavior, W_C, in (29) in the period 2000 to 2017, and considering the consumption at time 0, the values obtained from the inter-industry relocation measure S_i^B, the sensitivity of relocations to consumption $\widehat{\kappa}_{China} = 0.9357$, $\widehat{\kappa}_{India} = 0.3889$, $\widehat{\kappa}_{Brazil} = 0.1435$, $\widehat{\kappa}_{Brazil} = 0.1435$, $\widehat{\kappa}_{Colombia} = 0.4146$, $\widehat{\kappa}_{Chile} = 0.0716$ and $\widehat{\kappa}_{Mexico} = 0.0301$, and considering the real economic growth rate between the North and each South country, g, in (31). Through this procedure we can calculate and observe the interaction of welfare over time – see Figure 7. In each subFigure the solid green line represents the welfare levels between the US and the South, the dashed blue line illustrates the effective relocation measure S_i^B, and the dashed red line describes the real economic growth rate between the US and the South region, g. Furthermore, to improve our welfare analysis, we decided to estimate the trend effect followed by this variable in the period 2000 to 2017. Results of this estimation are exhibited in Appendix E.

According to Figure 7, although welfare has substantial decline in 2008 and 2009 due to external factors such as crisis, this variable does not show significant changes over time. To capture the trend behavior, we started to test the existence of structural breaks through the Chow test, dividing the period in three subsamples. In other words, we evaluate if there occurred structure collapses before (2000 to 2007), during (2008 and 2009) or after the crisis (2010 to 2017). Considering the results exposed in Appendix E – specification (*a*) –, we reject the null hypothesis in all the estimations for a significance level of 1%. Hence, these structural breaks are present in all regions.

Therefore, using the information obtained previously, it was possible to estimate the models – also disclosed in Appendix E – in specification (*b*) and (*c*). The specification (*b*) has as explanatory variables: trend, additive dummy variables for crisis and after crisis period, and also multiplicative dummies variables with the trend. The estimates in final specification (*c*) only consider the statistically significant variables. *Dcrisis* is a binary variable that assumes the value 1 in the years of recession $[2008, 2009]$ and 0 otherwise, and *Dafter* that takes the value 1 in the years following the recession $[2010, 2017]$ and 0 otherwise. Furthermore, the Tables show the trend variable is not statistically significant in any of the countries, which means that the welfare values do not follow an upward or downward tendency. These results fluctuate around a long-run stationary mean. Considering the remaining variables, in each estimation, excluding China, India and Mexico, only the variable *Dcrisis* in both additive and multiplicative forms and the variable *Dafter* for Colombia are statistically significant. Although there was a decline in 2008 and 2009, in the following years the welfare values converge again to the long-run equilibrium. In the case of China, India and Mexico, the welfare behavior after crisis is distinct when compared to the other countries. During the recession, *Dcrisis* in both additive and multiplicative forms are statistically significant and we perceive that welfare declines, respectively, annually 0.0080, 0.0099 and 0.0193. After the recession, according to the estimations, we recognize that *Dafter* in additive and multiplicative form are statistically significant and, therefore, welfare increases annually 0.0018, 0.0022 and 0.0018, according to the same order of countries.

Figure 7: Welfare values according to the inter-industry relocation measure, real economic growth rate and $\widehat{\kappa}_{China} = 0.9357$, $\widehat{\kappa}_{India} = 0.3889$, $\widehat{\kappa}_{Brazil} = 0.1435$, $\widehat{\kappa}_{Brazil} = 0.1435$, $\widehat{\kappa}_{Colombia} = 0.4146$, $\widehat{\kappa}_{Chile} = 0.0716$ and $\widehat{\kappa}_{Mexico} = 0.0301$



6 Econometric model

In this Section our main goal is to support the findings obtained for inter-country wage inequality defined in (24) and for social welfare stated in (29). We decided to analyze the impact of relocations only on these two variables since, compared to economic growth, their research is not considered deep in the literature. With that purpose, a two-stage least squares (2SLS) regression will be used in a SEM, similar to the one previously used in Subsection 5.1. However, now we will consider that the scale effects, γ_L, parameter will assume values such as 0, 0.5 and 1. This model allows us to tackle the endogeneity and, consequently, study the cause-effect relationship between the endogenous and exogenous variables.

The estimations produced, using the 2SLS with four equations SEM are revealed in Appendix F. Results obtained from equation (a), reveal that, for China, India and Chile, both variables are statistically significant and exhibit the same estimates, according to any scale effect value. For this group of countries, if wage inequality rises 1%, there will be, respectively, an estimated decrease in relocations of 0.0016 pp, 0.0002 pp and 0.0004 pp, *ceteris paribus* (c.p). If trade openness increases 1 pp, there will be, respectively, an estimated increase in relocations of 17.71 pp, 3.91 pp, and 1.69 pp, c.p. This shows that the estimates of $\phi_1$and ϕ_2 are higher for China when compared with the other two regions, as predicted. Concerning Brazil, we observed that none of them is statistically significant. As shown in Section 3 and taking into account the relocation values for this country, provided by (1), we perceive that when we analyze the trend and compare the first and the last year, the relocation growth is considerably low. Thus, there is an indication that the country may be stabilizing relocation levels and may be more interested in the specialization of final products, instead of intermediate goods. For Colombia, only the wage inequality variable is statistically significant, and for different scale effects values, the estimates remain the same. Hence, if wage inequality increases 1%, there will be an estimated decline in relocations of 0.0001 pp, c.p. Using the relocation levels calculated through the (1), we perceive that this country, like Chile, assumes low values when compared to the other countries under study. Moreover, Colombia's main exports are not related to intermediate goods, but to final products such as crude petroleum, coffee, spices and other commodities. This evidence could be one of the reasons why the trade openness for intermediate goods is not a critical factor. Mexico, as we noticed throughout the research, is the region with the greatest relocation levels. For this country, only the trade openness is statistically significant, and the results obtained through the estimations made reveal to be the same in the presence of a *market-size effect* or *price effect*. Hereupon, if the trade openness boosts 1 pp, there will be an estimated reduction in relocations of 3.42 pp, c.p. In this case, the location of this country, close to the US, associated with a significant trade openness may be the major drivers that lead to improvements in the relocation activity.

For equations (*b*), (*c*) and (*d*), we got estimates for the parameters μ and κ. Regardless of the scale effect value, all variables are statistically significant for the countries. The marginal effect of the relocation variable on the wage inequality and welfare can be computed as

$$\frac{\partial \ln\left(\frac{W_N}{W_S}\right)}{\partial \ln \ell} = 0 \Leftrightarrow \frac{\partial \ln\left(\frac{w_N}{w_S}\right)}{\partial \ln \ell} = -\frac{\mu}{2}$$

and

$$\frac{\partial W_C}{\partial \ell} = 0 \Leftrightarrow \frac{\partial W_C}{\partial \ell} = \frac{1.85k\ell^{-0.54k-1}}{0.015 + 0.54g}.$$

Moreover, if we consider the *market-size effect*, $\gamma = 0$, we conclude that if the relocation level, linked to equation (*b*), ℓ, increases by 1%, there will be an estimated decrease for the same order of countries mentioned before, respectively, in the wage inequality of 2.95%, 2.51%, 2.01%, 1.48%, 1.18% and 2.09%, c.p. For $\gamma = 0.5$, if the relocation activity, rises by 1%, there will be an estimated decline, for China, India, Brazil, Colombia, Chile and Mexico, in the wage inequality of 2.96%, 2.50%, 2.01%, 1.48%, 1.17% and 2.07%, respectively. If we consider a *price-effect*, $\gamma = 1$,for China, India, Brazil, Colombia, Chile and Mexico, in the case of the relocation levels, increases by 1%, there will be an estimated decrease in the earnings inequality of 2.97%, 2.48%, 2.00%, 1.46%, 1.16% and 2.05%, c.p. Regarding welfare function, exhibited in equation (*d*), if the relocation level rises 1% for the same order of regions mentioned earlier, there will be an estimated improve of 1059.45, 738.96, 261.72, 6575.99, 236.69, and 27.09 welfare units in the dependent variable, regardless the scale effect values.

Hence, regardless of the presence or absence of the *market size effect,* an improvement of 1% in relocation level leads, without exception and as expected, to a decline in inter-country wage inequality. As the scale effects value boosts for countries such as China, the estimated results for the relocation parameter, μ, increase, which means that an enhancement in the relocation activity has a more substantial impact on wage disparity. For the remaining countries, the interpretation occurs in a reverse direction. In other words, as the scale effects value grows, the estimated parameter, μ, results decrease, which indicates that an increment in the relocation level has a lower repercussion on wage inequality. Furthermore, we also concluded that in countries as China, India and Mexico, where the relocation performance and its growth is higher, a positive variation of 1% in relocation activity causes a greater decrease in earnings inequality between these countries and the US when compared to the other countries where the relocation level and its expansion is shallow.

With respect to social welfare, we notice that, according to the interpretations developed earlier, an increase in the relocation activity of 1% generates positive impacts on the consumers' welfare, in each pair of countries. Thus, the countries that reveal greater results when the relocation levels boost by 1% are China, India and Colombia. This situation occurs because these countries exhibit high estimated values of relocation sensitivity to consumption, κ. In turn, the remaining countries present low estimated values of relocation sensitivity to consumption, which means that the impact on welfare when the relocation increases by 1% will be smaller.

7 Concluding remarks

The impact of globalization on the countries' economic performance has been one of the most discussed topics since the post-war period. The main factors that contributed to this process were, definitely, the reduction in transport costs and the improvements in communication between countries, provoked by the technological-knowledge progress and innovation (Frankel 2000). This continued progress of globalization has led to a significant boost in cohesion, connection and integration among the different countries (Lee and Vivarelli 2006) and has induced and stimulated the relocation of productions (Alcalá and Solaz 2018a), which led to several changes in wages and economic growth in the North and the South countries. Considering the rising importance of this issue, we have analyzed the effects of relocations on wages, growth rates and social welfare.

We have developed a theoretical model that provide us the inter-country wage inequality measure, economic growth rate and social welfare for each pair of North-South countries. Subsequently, we constructed quantitative results based on the model. This approach allowed us to evaluate the magnitude of the relocations of each pair of countries, and how wage inequality, economic growth and social welfare react considering different scale effects and a few estimated values of relocation sensitivity to wage inequality and economic growth, and of relocation sensitivity to social welfare. Lastly, we also analyze the trend of consumers' welfare behavior.

Concerning the magnitude of theoretical relocations, we note that this activity is mainly developed in China, India and Mexico and has been growing substantially over time, particularly in Asian countries, if we are facing a *market-size effect* or a *price-effect*. However, for China, the growth of this activity is lower as the scale-effect values increase. For the remaining countries, the non-presence of a *market-size effect* produces the opposite repercussions. Given these results and through our relative return of North-labor function, we perceive that wage inequality between each pair of regions decreases significantly as the values of relocations increases. In other words, the wages paid to workers located in South countries have been accelerating and converging to the earnings paid to workers established in the North, which indicate that relocations reveal a positive and important impact on the labor market. Additionally, when we capture the behavior of the dependent variable under study, considering a range of values for the relocation sensitivity and regardless of the presence or the absence of scale effects, we conclude that wage inequality decreases substantially as the relocation sensitivity boosts. Considering the presence of scale effects, there is a higher decrease in wage disparity for each pair of regions, except in the case of China and India. However, these two Asian countries are the ones that exhibit the major impact on wage inequality when there is a fluctuation in the relocation sensitivity, as predicted since they are the countries with the largest relocation levels growth. In turn, Colombia and Chile present a smooth decline in wage inequality when there is a variation in the relocation sensitivity. This occurs because both countries reveal low relocation levels and small activity growth.

With respect to the reaction of economic growth among each pair of North and South countries, we perceived that an increase in the relocation sensitivity leads, without exception, to an improvement, on average, of the dependent variable, notwithstanding the presence or absence of scale effects. However, it is evident that this enhancement is more pronounced when the scale effects are removed; that is, when only the *price effect* is present. Thus, Brazil, Mexico and Colombia are the countries that exhibit a considerable boost in economic growth as the parameter of relocation rise. In turn, the remaining countries reveal a lower growth rate as the relocation sensitivity rise. For countries such as China, India and Chile, a significant boost in relocation sensitivity would be necessary for economic growth to increase substantially.

Regarding social welfare, when we evaluated the trend behavior we concluded that the variable does not follow an upward or downward trend in all countries, except in China, India and Mexico. In other words, the welfare results fluctuate around a long-run stationary mean, although between the period 2008 and 2009 there was a structure collapse due to the crises. For the three countries considered as an exception, the dependent variable increases before and after the recession, and during the breakdown decreases. Thus, we perceived that between the years where the strong declines occur, consumers experience a considerable loss of welfare caused by a fall in the relocation levels and economic growth.

In order to support the outcomes provided from the theoretical model and quantitative results, we used a 2SLS regression in a SEM to examine the impact of relocation activity on wage inequality and social welfare, considering the presence or the non-presence of a *market-size effect*. According to the estimated results obtained, we realized that regardless of the scale effects value, both independent variables – relocation sensitivity, μ, and relocation sensitivity to consumption, κ – are statistically significant for any pair of countries. Thus, considering the marginal effect of the relocation variable on the wage inequality, results that an improvement of 1% in the relocation level leads, in all cases, to a decline in the inter-country wage inequality. For countries such as China, India and Mexico, this increase in relocation stimulates a higher decrease in the wage inequality, as expected, since the relocation activity, in these countries, is already extremely developed, when compared to the remaining countries. With regard to the marginal effect of the relocation variable on social welfare, we concluded that enhancement in relocation level causes positive impacts on the welfare. This impact is larger in countries like China, India and Colombia, where the estimated values of relocation sensitivity to consumption are higher. In countries such as Brazil, Chile and Mexico, where the estimated results of relocation sensitivity to consumption are lower, the repercussions on welfare are, as predicted, less significant, although positive.

Relocation activities provide multiple advantages, in particular for firms. Lower labor costs and costs savings in utilities, infrastructures and materials are a few examples of the benefits derived from this activity that lead to higher profits. However, improvements are not only experienced in the business environment. With the relocation of activities to developing countries where unskilled labor is required new jobs are created, which causes a decrease in the unemployment rate and an increase in workers' wages. The governments of North countries will have a better opportunity to support additional R&D projects, raise their spending on infrastructures and technologies that encourage innovation and, they can invest, more deeply, in human capital. With the enhancement of relocation, the government will benefit from reduced costs of doing business with South countries, since they provide tax advantages that attract institutions located in the North. This situation stimulates the developing countries's economy and leads to fast economic growth. Finally, concerning consumers, we shows that their welfare would experience a substantial increase because they will be able to purchase a similar final product at a lower cost due to an improvement in production efficiency.

In conclusion, although through the analysis conducted based on the theoretical model and according to the findings drawn from the quantitative results and the econometric model be possible to deduce that relocations and relocation sensitivity contribute positively to an improvement in wages, economic growth and social welfare. It would be interesting, in future research, include other developed and innovative countries in addition to the US. In this sense, it would be possible to investigate in more depth the impacts of relocations on the variables in question and compare the different effects provided by each North country.

Appendix A

From the standard Optimal Control Theory, we consider the auxiliary Hamiltonian function,

$$H = \left[\frac{(C(t)\cdot \ell^{\kappa})^{1-\theta}-1}{1-\theta} - \frac{L_i^{1+\varphi}}{1+\varphi}\right] e^{-\rho t} + \lambda(t)\left\{r(t)\cdot a(t) + \sum_{S=L,H} \cdot w_i(t)\cdot L_i - C(t)\right\}$$

where a is the state variable; λ is the costate variables; C and S are the control variables. Then, the necessary conditions under the Maximum Principle are:

$$\frac{\partial H}{\partial C(t)} = 0 \Leftrightarrow \frac{1}{C(t)}\left(C(t)\cdot \ell^{\kappa}\right)^{1-\theta} e^{-\rho t} - \lambda(t) = 0 \tag{33}$$

$$\frac{\partial H}{\partial S(t)} = 0 \Leftrightarrow L_i^{\varphi}\cdot e^{-\rho t} + \lambda(t)\cdot w_i(t) = 0 \tag{34}$$

$$\frac{\partial H}{\partial a(t)} = -\dot{\lambda}(t) \Leftrightarrow r(t) + \frac{\dot{\lambda}(t)}{\lambda(t)} = 0 \tag{35}$$

$$\frac{\partial H}{\partial \lambda(t)} = \dot{a}(t) \tag{36}$$

$$\lim_{t\to+\infty} \lambda(t)\cdot a(t) = 0. \tag{37}$$

Rearranging (33) we have $C(t)\cdot\lambda(t) = \left(C(t)\cdot \ell^{\kappa}\right)^{1-\theta} e^{-\rho t}$. Then, log-differentiating this result with respect to time we have $\frac{\dot{\lambda}(t)}{\lambda(t)} = -\theta\frac{\dot{C}(t)}{C(t)} + \kappa\left(1-\theta\right)\frac{\dot{\ell}(t)}{\ell(t)} - \rho$. Moreover, bearing in mind (35) we obtain (4):

$$\frac{\dot{C}(t)}{C(t)} = \frac{1}{\theta}\cdot\left(\kappa\left(1-\theta\right)\frac{\dot{\ell}}{\ell} + r(t) - \rho\right) \Rightarrow g = \frac{1}{\theta}\cdot\left(r(t)-\rho\right), \tag{38}$$

since in the balanced growth path $\frac{\dot{\ell}(t)}{\ell(t)} = \frac{\dot{\ell}}{\ell} = 0$. Hence, dividing (34) across labor supply in the North, L_N, or in the South, L_S, we find (5):

$$\frac{w_N}{w_S} = \left[\frac{L_N}{L_S}\right]^{\varphi}. \tag{39}$$

Furthermore, the transversality condition is also standard: $\lim_{t\to\infty} e^{-\rho t}\cdot C(t)^{-\theta}\cdot a(t) = 0.$

Appendix B

From the utility function we can write the welfare along the balanced growth path $W_C = \frac{1}{1-\theta}\int_0^\infty \left\{\left[\ell^\kappa \cdot C(0)e^{gt}\right]^{(1-\theta)} - 1\right\} e^{-\rho t}dt - \int_0^\infty \left[\frac{L_i^{1+\varphi}}{1+\varphi}\right] e^{-\rho t}dt$, where $C(t) = C(0)e^{gt}$, g is given by (28), and $C(0)$, ℓ and L_i are also known. To put it simply, it comes

$$W_C = \frac{(C(0)\cdot\ell^\kappa)^{1-\theta}}{1-\theta}\int_0^\infty e^{[(1-\theta)g-\rho]t}dt - \frac{1}{1-\theta}\int_0^\infty e^{-\rho t}dt - \frac{L_i^{1+\varphi}}{1+\varphi}\int_0^\infty e^{-\rho t}dt.$$

Thus, we need to calculate:

$$W_C = \underbrace{\frac{(\ell^\kappa\cdot C(0))^{1-\theta}}{(1-\theta)\left[(1-\theta)g-\rho\right]}\left[\lim_{t\to\infty} e^{[(1-\theta)g-\rho]t}-1\right]}_{=A} + \underbrace{\frac{1}{(1-\theta)\rho}\left[\lim_{t\to\infty} e^{-\rho t}-1\right]}_{=B} + \underbrace{\frac{L_i^{1+\varphi}}{(1+\varphi)\rho}\left[\lim_{t\to\infty} e^{-\rho t}-1\right]_0^\infty}_{=C}. \quad (40)$$

In (40), $(1-\theta)g-\rho$ can be less than, equal to or greater than zero resulting, respectively, in $A = \frac{(C(0)\cdot\ell^\kappa)^{1-\theta}}{(1-\theta)[\rho-(1-\theta)g]}$, $A = 0$ or A divergent. In turn, $-\rho$ is less than zero resulting in $B = -\frac{1}{(1-\theta)\rho}$ and $C = -\frac{L_i^{1+\varphi}}{(1+\varphi)\rho}$. Supposing, as expected from the data, that $(1-\theta)g-\rho < 0$, we have an expression for the infinite-horizon welfare (29):

$$W_C = \frac{1}{1-\theta}\left\{\frac{(C(0)\cdot\ell^\kappa)^{1-\theta}}{[\rho-g(1-\theta)]} - \frac{1}{\rho}\right\} - \frac{L_i^{1+\varphi}}{(1+\varphi)\rho}.$$

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Appendix C

Table 2: ln(offshoring) - trend behavior and growth rate of relocation activity in the period 1997 and 2017 for China, India, Brazil, Colombia, Chile and Mexico

Explanatory	**China**		**India**		**Brazil**		**Colombia**			**Chile**		**Mexico**	
variables	(a)	(b)	(a)	(b)	(a)	(b)	(a)	(b)	(c)	(a)	(b)	(a)	(b)
Constant	-2.6762*	-2.9783*	-3.4226*	-3.4046*	-3.1425*	-3.3379*	-5.2675*	-5.2421*	-5.2946*	-4.2310*	-4.6068*	-2.4869*	-2.5094*
	(0.163)	(0.090)	(0.044)	(0.047)	(0.108)	(0.098)	(0.107)	(0.102)	(0.103)	(0.178)	(0.132)	(0.044)	(0.047)
Trend	0.0687*	0.1313*	0.0528*	0.0458*	0.0159**	0.0617*	0.0660*	0.0478**	0.0630*	0.0385**	0.1195*	0.0354*	0.0376*
	(0.013)	(0.015)	(0.004)	(0.008)	(0.007)	(0.015)	(0.014)	(0.016)	(0.013)	(0.016)	(0.024)	(0.006)	(0.008)
Dcrisis		6.3731*		4.3171*		7.1149*		-0.0018			7.0040*		2.6241*
		(0.090)		(0.047)		(0.098)		(0.102)			(0.132)		(0.047)
Dcrisis × trend		-0.5682*		-0.3721*		-0.6544*		0.0219			-0.6493*		-0.2354*
		(0.015)		(0.008)		(0.015)		(0.016)			(0.024)		(0.008)
Dafter		1.2598*		0.5745*		0.6679**		2.2545*	2.3070*		1.8800*		0.9906*
		(0.144)		(0.089)		(0.287)		(0.381)	(0.343)		(0.323)		(0.176)
Dafter × trend		-0.1256*		-0.0271		-0.0761*		-0.1156*	-0.1307*		-0.1761*		-0.0587*
		(0.014)		(0.008)		(0.021)		(0.028)	(0.022)		(0.022)		(0.010)
Adjust. R-squared	0.7558	0.9478	0.8875	0.9338	0.1402	0.5229	0.6723	0.8275	0.8324	0.3181	0.6809	0.7616	0.8970
Wald F-stat. value	27.2665	73.6886	198.7251	57.4408	4.6386	5.3837	22.7260	20.1944	34.1090	5.9891	9.5338	41.2812	35.8171
p-value	0.0000	0.0000	0.0000	0.0000	0.0443	0.0050	0.0001	0.0000	0.0000	(0.024)	0.0003	0.0000	0.0000
Chow stat. value	18.4862		4.3231		4.8094		5.2768			6.3995		7.2380	
p-value	0.0000		0.0160		0.0107		0.0074			0.0033		0.0019	
Sample size	21	21	21	21	21	21	21	21	21	21	21	21	21

Notes: (i) heteroskedasticity and autocorrelation consistent (HAC) standard errors in parentheses; (ii) *, **, *** denotes significant at 1%, 5% and 10%, respectively.

Appendix D

Table 3: Estimates of the parameters using the SEM, 2SLS

Estimates of the parameters	**China**	**India**	**Brazil**	**Colombia**	**Chile**	**Mexico**
$\widehat{\mu}$	5.8178*	5.3470*	4.5860*	3.0711*	2.4794*	5.0053*
	(0.086)	(0.093)	(0.140)	(0.053)	(0.080)	(0.132)
$\widehat{\kappa}$	0.9357*	0.3889*	0.1435**	0.4146*	0.0716**	0.0301*
	(0.072)	(0.070)	(0.057)	(0.012)	(0.032)	(0.005)
Sample size	17	14	12	14	17	17

Notes: (i) HAC standard errors in parentheses; (ii) *, **, *** denotes significant at 1%, 5% and 10%, respectively.

Appendix E

Table 4: Welfare - trend behavior in the period 2000-2017 for China, India, Brazil, Colombia, Chile and Mexico

Explanatory	China			India			Brazil			Colombia			Chile			Mexico		
variables	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
Constant	0.0319*	0.0421*	0.0349*	0.0321*	0.0426*	0.0328*	0.0350*	0.0378*	0.0281*	0.0325*	0.0390*	0.0329*	0.0358*	0.0362*	0.0326*	0.0328*	0.0458*	0.0328*
	(0.007)	(0.010)	(0.003)	(0.008)	(0.010)	(0.003)	(0.002)	(0.010)	(0.002)	(0.007)	(0.009)	(0.002)	(0.006)	(0.010)	(0.002)	(0.009)	(0.011)	(0.004)
Trend	-0.0002	-0.0011		-0.0006	-0.0015		-0.0008	-0.0008		-0.0006	-0.0009		-0.0006	-0.000		-0.0008	-0.0020	
	(0.001)	(0.001)		(0.001)	(0.001)		(0.001)	(0.001)		(0.001)	(0.001)		(0.000)	(0.001)		(0.001)	(0.001)	
Dcrisis		0.0496*	0.0568*		0.0655*	0.0753*		0.1014*	0.1111*		0.0940*	0.1000*		0.1639*	0.1675*		0.1655*	0.1785*
		(0.010)	(0.003)		(0.009)	(0.003)		(0.010)	(0.002)		(0.010)	(0.002)		(0.010)	(0.002)		(0.011)	(0.004)
Dcrisis × trend		-0.0069*	-0.0080*		-0.0084*	-0.0099		-0.0111*	-0.0119*		-0.0110*	-0.0119*		-0.0176*	-0.0177*		-0.0173*	-0.0193*
		(0.001)	(0.000)		(0.001)	(0.000)		(0.001)	(0.000)		(0.001)	(0.000)		(0.001)	(0.000)		(0.001)	(0.000)
Dafter		-0.03977**	-0.0325*		-0.0540*	-0.0442*		-0.0142			-0.0338**	-0.0075**		0.0042			-0.0516*	-0.0385*
		(0.014)	(0.010)		(0.014)	(0.011)		(0.013)			(0.013)	(0.003)		(0.015)			(0.015)	(0.011)
Dafter × trend		0.0029***	0.0018*		0.0037**	0.0022*		0.0008			0.0022			-0.0006			0.0038**	0.0018**
		(0.001)	(0.001)		(0.001)	(0.001)		(0.001)			(0.001)			(0.001)			(0.002)	(0.001)
Adjust. R-squared	-0.0559	0.6699	0.6721	-0.0031	0.7172	0.7024	0.1022	0.6164	0.5057	0.0019	0.7076	0.7080	-0.0019	0.7001	0.6942	0.0051	0.7049	0.6768
Wald F-stat. value	0.1195	7.9013	9.7131	1.0007	9.6218	11.0326	2.1019	6.4631	9.6969	1.4407	9.2278	14.7367	2.5119	8.9352	0.0000	1.2477	9.1225	0.0007
p-value	0.7341	0.0017	0.0007	0.3320	0.0007	0.0004	0.1664	0.0039	0.0020	0.2475	0.0008	0.0001	0.1326	0.0010	0.0000	0.2805	0.0009	0.0000
Chow stat. value	9.7967			11.1872			6.3615			10.6543			10.3612			10.4868		
p-value	0.0009			0.0005			0.0055			0.0006			0.0007			0.0007		
Sample size	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18

Notes: (i) HAC standard errors in parentheses; (ii) *, **, *** denotes significant at 1%, 5% and 10%, respectively.

Appendix F

Table 5: Estimation of the parameters using the SEM, 2SLS

Estimation of	China			India			Brazil			Colombia			Chile			Mexico		
parameters	$\gamma = 0$	$\gamma = 0.5$	$\gamma = 1$	$\gamma = 0$	$\gamma = 0.5$	$\gamma = 1$	$\gamma = 0$	$\gamma = 0.5$	$\gamma = 1$	$\gamma = 0$	$\gamma = 0.5$	$\gamma = 1$	$\gamma = 0$	$\gamma = 0.5$	$\gamma = 1$	$\gamma = 0$	$\gamma = 0.5$	$\gamma = 1$
Φ_1	-0.1626*	-0.1626*	-0.1626*	-0.0224*	-0.0224*	-0.0224*	0.0153	0.0153	0.0153	-0.0147*	-0.0147*	-0.0147*	-0.0448*	-0.0448*	-0.0448*	0.0849	0.0849	0.0849
	(0.024)	(0.024)	(0.024)	(0.002)	(0.002)	(0.002)	(0.014)	(0.014)	(0.014)	(0.005)	(0.005)	(0.005)	(0.008)	(0.008)	(0.008)	(0.087)	(0.087)	(0.087)
Φ_2	17.7097*	17.7097*	17.7097*	3.9097*	3.9097*	3.9097*	-0.5767	-0.5767	-0.5767	0.1137	0.1137	0.1137	1.6917*	1.6917*	1.6917*	3.4206*	3.4206*	3.4206*
	(3.511)	(3.511)	(3.511)	(0.886)	(0.886)	(0.886)	(1.414)	(1.414)	(1.414)	(0.644)	(0.644)	(0.644)	(0.195)	(0.195)	(0.195)	(0.818)	(0.818)	(0.818)
μ	5.8907*	5.9238*	5.9491*	5.0282*	4.9991*	4.9686*	4.0286*	4.0139*	3.9943*	2.9637*	2.9516*	2.9149*	2.3618*	2.3382*	2.3149*	4.1796*	4.1382*	4.0958*
	(0.136)	(0.138)	(0.141)	(0.050)	(0.050)	(0.051)	(0.148)	(0.151)	(0.155)	(0.036)	(0.034)	(0.036)	(0.050)	(0.050)	(0.050)	(0.070)	(0.072)	(0.074)
k	1.1215*	1.1215*	1.1215*	0.3889*	0.3889*	0.3889*	0.1559*	0.1559*	0.1559*	0.4146*	0.4146*	0.4146*	0.0716**	0.0716**	0.0716**	0.0462***	0.0462***	0.0462***
	(0.064)	(0.064)	(0.064)	(0.070)	(0.070)	(0.070)	(0.055)	(0.055)	(0.055)	(0.012)	(0.012)	(0.012)	(0.032)	(0.032)	(0.032)	(0.027)	(0.027)	(0.027)
Sample size	15	15	15	14	14	14	14	14	14	14	14	14	17	17	17	18	18	18

Notes: (i) HAC standard errors in parentheses; (ii) *, **, *** denotes significant at 1%, 5% and 10%, respectively.