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Lina Salazar
Diana Tadeo
Luis Alvarez

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Agricultural Productivity in the Latin America and Caribbean Region (1961-2021)

Lina Salazar
lsalazar@iadb.org

Diana Tadeo
dianata@iadb.org

Luis Alvarez
luisalv@iadb.org

Agricultural productivity has been a critical driver of economic growth in Latin America and the Caribbean (LAC) over the past six decades. However, while agricultural output is still rising, recent trends suggest a decline in agricultural productivity and an increasing reliance on input use, which could have harmful effects on the environment and natural resources. This study aims to analyze the historical trends of agricultural productivity in LAC while assessing the heterogeneous dynamics among subregions and countries, using a unique dataset compiled by the USDA, combined with FAO and ILO data for the period from 1961 to 2021. Agricultural productivity is essential for addressing LAC's interconnected challenges of poverty, food insecurity, and climate change. Hence, understanding its drivers is key to designing comprehensive policies to improve efficiency and ensure long-term sustainable development across the region.

1. Introduction

Agricultural productivity lies at the nexus of the Latin America and the Caribbean (LAC) region's major development challenges, including poverty, hunger, and climate change. Previous research has shown that investments in improving productivity in agriculture – where more than two-thirds of LAC's extreme poor and more than half of LAC's moderate poor are employed (Livelihoods, 2019) – have been more effective at poverty-reduction than taking the poor out of agriculture (Warr & Suphannachart, 2021; de Janvry & Sadoulet, 2010; Avila et al., 2010). Therefore, increasing agricultural productivity among subsistence farmers and the poor who rely on agriculture as a source of food and income remains vital in protecting the livelihoods of the region's most vulnerable.

Sustained agricultural productivity growth is also critical to ensure that LAC's growing population achieves adequate nutrition, an area where the region is underperforming. In fact, according to CEPAL's most recent report on the LAC region's progress towards the Sustainable Development Goals, LAC's progress towards achieving SDG2 (Zero Hunger) is regressing by several indicators (CEPAL, 2024). For instance, severe food insecurity rose from 7.5% in 2015 to 10.1% in 2019 (CEPAL, 2024). The Food and Agriculture Organization (FAO) has attributed increased food insecurity primarily to the unaffordability of nutritious food among the poor, rather than unavailability of food (FAO et al., 2023). In addition, the Inter-American Development Bank have confirmed that LAC is the region with the highest cost for accessing a healthy diet, causing that 11% of the children suffer from stunted growth and 24% of adults from obesity (IADB, 2024).

At the same time, climate change has introduced new complexities to agricultural productivity in the region. Rising temperatures and unpredictable rainfall patterns are expected to decrease crop yields, change agricultural viability for certain crops, increase vulnerability of agriculture to plagues, among others, further exacerbating the region's food affordability crisis (Akzar & Amandaria, 2021; Gornall et al., 2010). Regarding climate change, agriculture plays a dual role. On one hand, it is the only sector in the economy with the ability to sequester carbon/ and therefore mitigate climate change, through nature-positive production systems. On the other hand, agriculture also contributes to climate change through changes in land use, deforestation, and the use of harmful inputs (Akzar & Amandaria, 2021; Anderson et al., 2020). Hence, while productivity gains are essential for poverty reduction and food security, it is essential for any productivity gains to be driven by nature positive practices while avoiding the expansion of the agricultural frontier and the intensification through harmful input intensification, both of which can threaten biodiversity and undermine climate mitigation efforts. These challenges call for a thorough analysis of LAC's agricultural productivity trends, with the goal of informing policy decisions that address poverty and hunger while also mitigating climate change impacts.

Several studies have examined agricultural productivity growth in the LAC region, with Total Factor Productivity (TFP) serving as the primary metric for assessing productivity gains. TFP accounts for output growth not explained by input increases, making it a valuable tool for understanding how efficiently resources like land, labor, and capital are being used in agriculture. Research by Avila et al. (2010) and Ludena (2010) reveals that the LAC region has experienced substantial TFP growth, particularly in Argentina, Chile, and Brazil. In contrast, Caribbean and Central American nations have struggled, with some experiencing negative TFP growth rates. During the 1990s, LAC reached a peak in productivity growth, but this trend slowed in the 2000s. Ludena (2010) found that, although LAC was one of the top-performing regions globally in terms of TFP growth—only trailing high-income countries—there was a notable deceleration in productivity after the mid-1990s. This deceleration was primarily attributed to declining efficiency, even though recent technologies continued to drive some productivity gains. Interestingly, land-abundant countries such as Argentina, Colombia, and Chile performed much better than those with limited land resources, a pattern that persisted throughout the decades analyzed.

Building on this, Nin-Pratt et al. (2015) conduct a detailed study of TFP growth from 1981 to 2012. Their findings show an acceleration in TFP growth during this period, with the region producing 35% more output in 2012 compared to 1980, despite using the same level of inputs. Macroeconomic conditions, rising commodity prices, and greater input use—particularly land and fertilizer—played key roles in driving this growth. The study emphasizes that the LAC region's TFP growth in the early 2000s not only represented an improvement over previous decades but also narrowed the productivity gap between the region and OECD countries. Countries like Brazil and Costa Rica stood out as top performers, achieving TFP growth rates of around 2.5%, while Haiti and Barbados saw declines in agricultural productivity.

Using novel methods and data sources, Sotelsek-Salem and Laborda-Castillo (2019) offer insights into agricultural Total Factor Productivity (TFP) across 19 LAC countries from 1989 to 2006. They employ cereal crop data from the World Bank and used the Lowe index to estimate TFP changes, finding an average annual growth rate of about 3%, like that of developed nations. The study suggests that previous research may have underestimated productivity by using the Malmquist index, which would have shown a lower growth rate of 1.5%. Despite differences in TFP estimates, overall trends align with prior studies, with Brazil and Costa Rica showing the strongest growth, while Nicaragua, Guatemala, and Paraguay experienced negative trends. This study underscores the significance of innovative methodologies in assessing TFP dynamics and sheds light on the diverse landscape of agricultural productivity within the LAC region.

Another innovative approach comes from Lachaud and Bravo-Ureta (2021), who introduce the concept of Climate-Adjusted Total Factor Productivity (CATFP). Their study considers the growing impact of climate variables, such as rising temperatures and changing precipitation patterns, on agricultural productivity. They aim to explore whether countries with lower CATFP levels could catch up with higher-performing countries. The study found an average annual CATFP growth of 0.98 in the region, with technological advancements as the primary catalyst for growth. While convergence among countries is possible, the authors highlight that without targeted policy interventions, it remains uncertain. Brazil, Chile, and Costa Rica led in CATFP growth, underlining the key role of climate, technology, and policy in shaping agricultural productivity in LAC.

This study builds on existing literature to assess current trends of TFP in the LAC region, using data from USAID and FAOSTAT widely regarded as the most comprehensive source for cross-country comparisons on agricultural indicators in the LAC region. Like previous studies (e.g., Avila et al., 2010; Ludena, 2010; Nin-Pratt et al., 2015), we use Total Factor Productivity (TFP) as our primary productivity measure. However, we address significant gaps by extending the analysis of TFP beyond 2014, covering a 60-year period (1961-2021) across 25 countries. This analysis also decomposes output growth into four input categories—labor, land, capital, and materials—allowing for a more detailed examination of the drivers behind TFP growth and output trends across time, regions, and countries, following the methodology proposed by Fuglie (2012). The previous information allows for cross-country and cross- subregional comparisons and is particularly relevant given the region's ongoing challenges of poverty, food insecurity and climate change vulnerability.

This paper is organized as follows: Section 2 provides a definition of agricultural TFP and explains why it serves as a preferred measure of productivity. Section 3 describes the data sources and key variables used in the study, including labor, land, capital, and materials. Section 4 presents the findings, detailing TFP trends and decomposition at regional and subregional levels. It also provides insights into the evolution of TFP from 1961 to 2021 and examines the sources of productivity growth. Section 5 compares multiple indices by country level from 1995 to 2021. Finally, Section 6 summarizes the main conclusions and policy implications of the study.

2. Total Factor Productivity Growth

According to Diewert (2001), the productivity of a production unit (e.g., a firm, an industry, or a country) is defined as the real output produced divided by the real input used over the same period. If the input measure is comprehensive, then we would obtain the productivity measure known as Total Factor Productivity (TFP).

The measurement of TFP in the agricultural sector considers all production inputs including land, labor, capital, and material resources utilized in farm production and compares them with the total gross output of crop, animal, and aquaculture products. In this sense, since it encompasses the comprehensive set of inputs used in production, it represents the average TFP for agricultural products.

TFP is defined as the ratio of total output to total input:

$$TFP_t = \frac{Y_t}{X_t} \tag{1}$$

However, in a multi-output, multi-input setting with heterogeneous production units, cross-country comparisons of TFP levels can only be applied across similar measurement units (Diewert, 2012). Nonetheless, the Index Number Theory approach enables us to derive meaningful definitions for output growth and input growth between any two periods (USDA-ERS, 2023; Caves et al., 1982). This method permits us to model TFP growth as the difference between output and input growth rates:

$$g(TFP_t) = \sum_i R_i g(Y_{it}) - \sum_j S_j g(X_{jt}) \tag{2}$$

The first term on the right-hand side of Equation (2) represents the total output growth rate. By specifying a Laspeyres functional form for the output index, we can estimate output growth as the sum of the growth rates of each output commodity i, weighted by its revenue share R_i. Similarly, the second term on the right-hand side gives the total input growth rate, which is defined as the sum of the growth rates of each input j, weighted by the output-input elasticity coefficients. According to Fuglie (2012), under the assumptions that both output and input markets are competitive, and the underlying technology of production is modeled as a constant returns-to-scale production function, then the output elasticity with respect to an input is equal to the cost share of that input S_j (see Appendix A for further details).

The methodology employed by Fuglie (2012) utilizes variable weights as cost shares like the Tornqvist–Thiel index to mitigate potential ‘index number bias’, in contrast to the Paasche and Laspeyres indexes which rely on fixed weights. This method yields internationally consistent and comparable growth rates and trends for agricultural TFP, although it does not provide TFP levels. It further diminishes short-term distortions in productivity resulting from economic shocks, offering a more accurate long-term perspective on the factors driving output growth in the LAC sector. Overall, the "growth accounting" method offers a practical means of tracking changes in agricultural TFP over time by leveraging data on agricultural outputs, inputs, and their respective prices.

This approach distinguishes TFP from metrics like crop yield per acre or agricultural value added per worker by considering a broader array of products and inputs in the production process (Fuglie, 2015). It enables the breakdown of all inputs for a detailed analysis of sector performance and growth drivers, facilitating comparisons. TFP decomposition allows for assessing the extent to which agricultural growth stems from increased inputs versus efficiency gains, indicating whether the region is achieving more output with less or equal amount of inputs or, on the contrary, relying on increasingly scarce inputs over time such as land.

By capturing the unexplained residuals of output growth, TFP reflects the average efficiency of all inputs involved in producing various agricultural goods. In sum, TFP growth mirrors the pace of technical advancements and efficiency improvements achieved by the agricultural sector.

For the purpose of studying TFP trends and determinants, we calculate four comparative index numbers, distinct from the widely used Malmquist index, namely: Lowe, Färe-Primont, Hicks-Moorsteen, and USDA estimates. Two of these indices—Lowe and Färe-Primont—are calculated with fixed prices, while the other two utilize variable prices. This approach allows us to observe overarching trends through different methodological lenses and serves as a sensitivity analysis. The Lowe quantity index is characterized by fixed, predetermined prices based on a specific base period, making it particularly valuable for long-term intertemporal analysis (Hill, 2010). Similarly, the Färe-Primont index also uses fixed shadow prices, derived through Data Envelopment Analysis (DEA) using FAO input and output quantities. These shadow prices are calculated by measuring the efficiency distance of each input and output relative to the efficiency frontier for each period. Consequently, changes in the Färe-Primont index capture variations in input quantities and technical efficiency, independent of shifts in relative prices (Shumway, R. et al, 2015).

The Hicks-Moorsteen index relies on variable prices. This index assesses inputs and outputs relative to the efficiency frontier across two periods. To determine shadow prices, we use Data Envelopment Analysis (DEA) to calculate the necessary distance measures for both output and input indices. In contrast, the USDA index employs variable weights that adjust each decade, helping to reduce the "index number bias" noted by Fuglie (2012). This bias can arise when producers alter their input and output choices based on relative profitability or costs (USDA, 2023).

3. Data

This study uses the USDA Economic Research Service *International Agricultural Productivity* (*IAP*) data product[1] to measure TFP. This dataset measures annual agricultural productivity data for over six decades (1961-2021) for regions, subregions and countries worldwide (see Appendix B for regional groupings).

3.1 Output Data

Agricultural output aggregates the gross value of 162 crop commodities, 30 animal products, and 9 aquaculture products (valued in thousands of U.S.

[1] U.S. Department of Agriculture, Economic Research Service. International Agricultural Productivity data product, September 2023.

dollars, at constant 2015 global average farmgate prices) provided by FAOSTAT and FAO's FISHSTAT (USDA, 2023). This data estimates agricultural output at the national, regional, and global levels and includes both food and non-food commodities (excluding harvested hay and fodder, as well as ornamental crops like flowers and shrubberies). Since constant end-period prices are used to construct the output measure, it is equivalent to a Paasche quantity index of real output (see Appendix A), which can be used to evaluate trends across regions and through decades. To calculate commodity prices, the FAO uses the Geary-Khamis method (Rao, 1993). The index is calculated by dividing the FAOSTAT measure of the Value of Agricultural Production by the gross quantity, with each commodity measured in $/metric ton.

3.2 Input Data

Using four inputs, we can construct an index of aggregate agricultural input from their weighted growth rates, where input cost shares are the weights (see subsection below). IAP data products provide quality-adjusted land measured in thousands of hectares of rainfed-cropland equivalents, labor in thousands of workers, capital in thousands of dollars, fertilizer in thousands of metric tons, and feed in MCal. Each of these variables is also represented in an index, with 2015 as the base year. The Materials Input Index is calculated by combining the feed and fertilizer indexes. In the following paragraphs, we discuss the sources and specifications of each of these input variables in more detail.

Labor is measured as the total number of economically active males and females aged 15 years and older, primarily employed in agriculture (in thousands of persons). It includes hired labor and unpaid family labor, as well as full-time and part-time workers. The main source for this information is the ILOSTAT labor force survey estimates.

Agricultural capital comprises various implements such as machinery and livestock (only reproducible capital is considered). FAOSTAT provides Net Capital Stock information from 1995 to the present, derived from the sum of past capital investments depreciated for wear and tear estimates using the Perpetual Inventory Method (PIM). To obtain information before 1995, IAP uses estimates from inventories of livestock and machinery capital. Farm inventories include livestock such as dairy cows, non-dairy cattle, buffaloes, sheep, goats, pigs, camels, poultry, camelids, horses for draft, mules, and asses, measured in thousands of Standard Livestock Units. The sizes were weighted by Hayami & Ruttan (1985). Farm machinery includes tractors, combinethreshers, and milking machines, measured in thousands of metric horsepower (1000 CV). This information is compiled from multiple sources. Data before 2010 comes from FAOSTAT, while data after 2010 is collected from the National Agricultural Censuses and from private sector data on sales (Fuglie, 2015). Total capital is the value of net machinery and livestock in thousands of dollars, using 2015 as the constant price year.

Agricultural land has been quality-adjusted to be measured in thousands of hectares of "rainfed-equivalent cropland." This adjustment allows to account for irrigated land and permanent pasture in our index, as they differ in their contribution to TFP. The main source of agricultural data is FAOSTAT, which includes information on temporary fallow and pastures, irrigated and rainfed areas, and permanent pasture. Productivity weights for the LAC region are derived from regression analysis (Fuglie, 2015) and a crop growth model by Siebert & Doll (2010). This approach assumes that 1 hectare of irrigated land is as productive as 1.626 hectares of rainfed cropland. Similarly, 1 hectare of permanent pasture is considered as productive as 0.03 hectares of rainfed cropland (See Table 1 below).

Table 1

Region	**Rainfed Cropland**	**Permanent Pasture**	**Irrigated Cropland**
Latin America and the Caribbean	1.000	0.030	1.795
Central America	1.000	0.030	1.605
Caribbean	1.000	0.030	1.626
South America	1.000	0.030	1.934

Source: Fuglie (2015) and Siebert& Doll (2010).

Agricultural materials are represented by a combined index of crop (fertilizers) and animal (feed) intermediate inputs, valued at constant 2015 prices. Fertilizer information includes inorganic NPK and organic N applied to soils[2], measured in metric tons. FAOSTAT provides the total quantities of N, P2O5, and K2O[3]. Animal intermediate input is measured by the total metabolizable energy from animal feeds in MCal. This includes an aggregate of 17 different animal feed sources: FAOSTAT Supply Utilization Accounts provide information after 2014, and FAOSTAT Commodity Balance Sheets provide information before 2014. Additionally, the USDA PS&D database offers information on oilseeds and vegetable oils. The energy content from feed types comes from the National Research Council (1982).

3.3 Cost Shares

To construct the total input index, all four inputs—land, labor, capital, and materials—are weighted by cost shares obtained from various sources, which vary by decade and region. Cost shares are an estimate of the share (or percentage) of total input costs assigned to each input. Twenty-one productivity studies have estimated cost shares or production elasticities, and these were collected by Fuglie (2015). Some of these cost shares are representative of countries within the same region, as not all countries have this information available. For example, Brazil's cost shares were assumed for other countries in South America. In some cases, data allows for the estimation of cost shares for each decade, facilitating the analysis of the evolution of inputs in comparison to other intermediate inputs.

4. Decomposition of Agricultural Output Growth and Results[4]

The IAP Data Product allows us to perform an exhaustive analysis of output growth and its decomposition. In the following sections, we present our results in various modalities, highlighting salient trends at the regional, subregional, and country levels. Section 4.1.1 presents a time series describing the evolution of TFP growth from 1961 to 2021 for the LAC region and its subregions. Section 4.1.2 describes the region's trends in average annual growth rates for agricultural output, TFP, and input growth, with individual country

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[2] Inorganic fertilizers, often called synthetic or chemical fertilizers, supply plants with three primary macronutrients: nitrogen (N), phosphorus (P), and potassium (K). Organic nitrogen (N) fertilizers are derived from plant or animal sources.

[3] The fertilizer grade or analysis indicates the percentages of three key nutrients in the material: nitrogen (N), phosphate (P2O5), and potash (K2O).

[4] For this analysis, we use the USDA index proposed by Fuglie (2012), reorganizing the regional groupings based on the Inter-American Development Bank's classification, as detailed in Appendix B.

performance highlighted through choropleth maps. This section also details average annual growth trends for the four major categories of inputs: land, capital, materials, and labor. The following sections analyze the drivers of the LAC region's output growth over the last six decades, offering a growth decomposition analysis that breaks down sources of growth into two categories: input growth and TFP growth.

4.1 TFP and aggregate input growth decomposition

The methodology developed in USDA-ERS (2023) allows us to decompose the relative contribution of TFP and inputs to output growth. A first decomposition between TFP growth and total input growth is given by Eq. (3):

$$g(Y_t) = g(TFP_t) + g(X_t) \tag{3}$$

4.1.1 Evolution of TFP Across the LAC Region

Figure 1 shows the evolution of agricultural TFP from 1961 to 2021 for the entire Latin America and the Caribbean (LAC) region, as well as for a subset excluding the top agricultural GDP performing countries: Argentina, Brazil, and Mexico. Both groups follow a similar trajectory until the mid-1990s. After this point, excluding the three largest economies results in a noticeably slower TFP growth rate for the region. Both groups experience similar steady TFP growth from 1961 through the 1990s, increasing by about 67% over those 30 years. However, after the 1990s, the TFP growth trajectories of top performing countries and the rest of the region start to diverge. Between 1990 and 2010, the entire LAC region's TFP increases by approximately 53%, while the subset excluding the top-performing countries grows by 26%, about half as much. In the last decade, TFP growth has slowed down significantly for both groups. In fact, the entire LAC region's TFP barely surpasses a 5% increase, while the subset excluding Argentina, Brazil, and Mexico grows by over 8%, indicating slightly better performance.

Figure 1: Evolution of TFP (1961–2021) for the LAC Region and Excluding Top GDP-Performing Countries

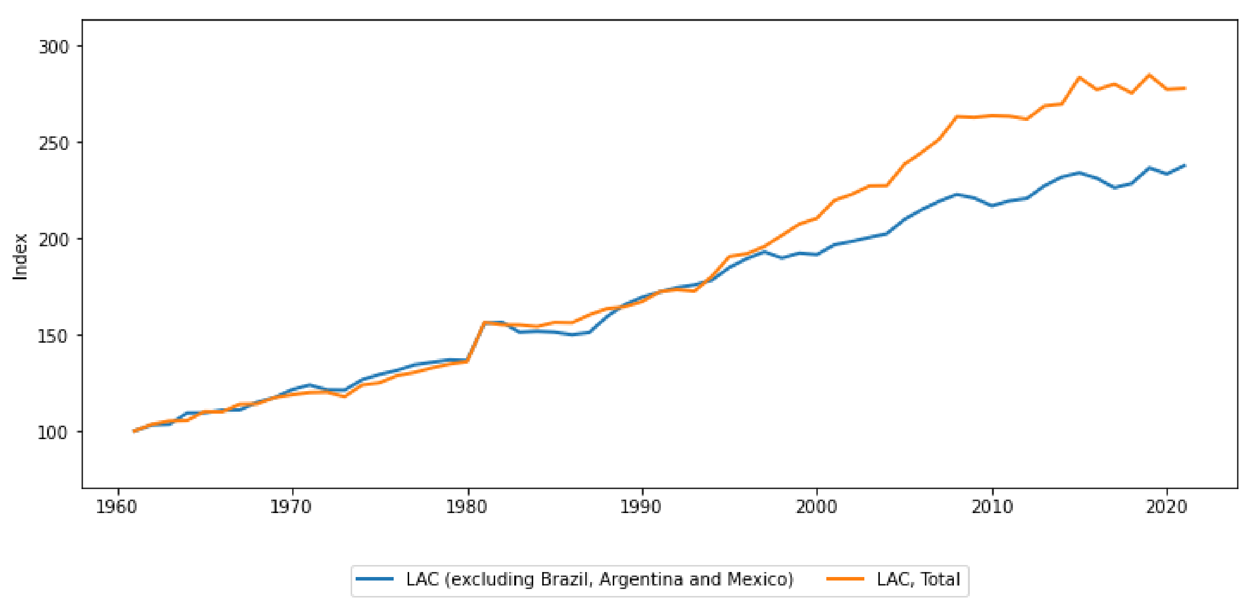


Figure 2 illustrates the evolution of agricultural TFP growth from 1961 to 2021 for each subregion in LAC. The index compares each subregion's annual TFP levels to their 1961 levels, showing the relative evolution of TFP over time. Mexico was excluded from the Central America subregion to avoid skewing the results, as its performance may have dominated the subregion's growth. As shown in Figure 2, all subregions exhibit similar TFP growth from 1960 to 1990. During these three decades, Mexico and the Central American countries outperformed other subregions. Central America saw stronger growth during the first two decades but experienced a slowdown afterwards.

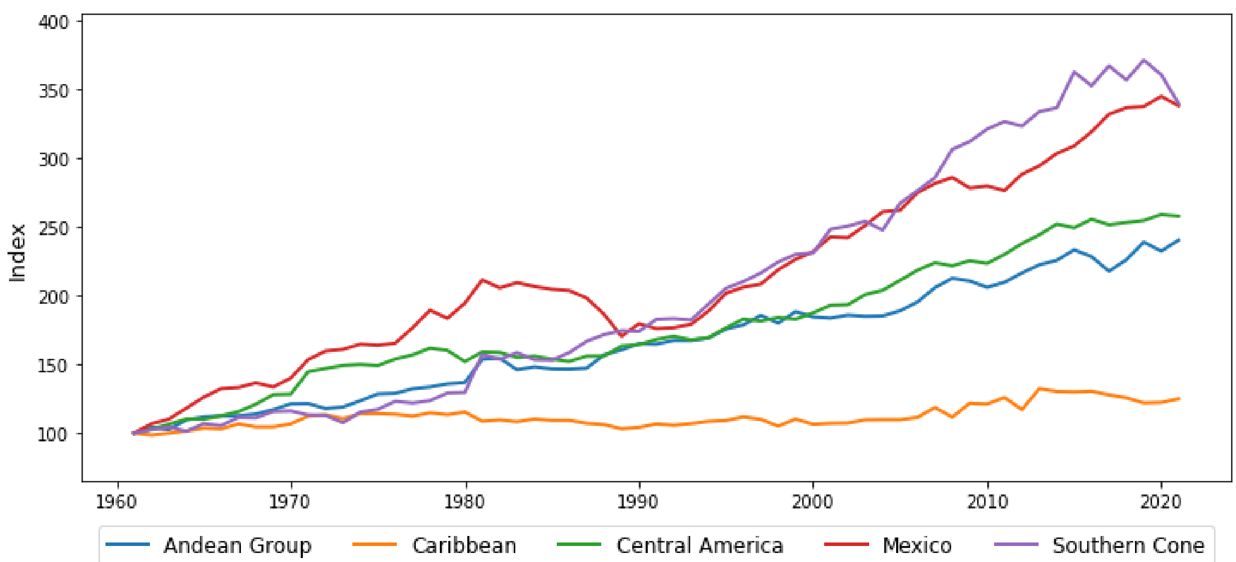
The Southern Cone (CSC) has sustained the highest productivity growth of any subregion over the last six decades, surpassing all others since the mid-1990s, with a cumulative growth of nearly 95%. Mexico follows closely, with an 88% growth rate. However, since 2015, TFP growth in the Southern Cone has slowed and become more volatile, with a decline of approximately 6%.

Over the six decades, Central America achieved the second-highest TFP growth in LAC, followed by the Andean Group (CAN). Central America grew by over 35% during the last two decades, while the Andean Region surpassed 30%. However, TFP growth in the Andean Group became slightly more volatile in the late 2010s, showing a modest increase of only 3% during that period.

The Caribbean (CCB) subregion exhibits a long-term stagnation in TFP, with an inflection point in the mid-1990s that marked the beginning of a modestly increasing trend over the last two decades. As of 2021, the CCB's productivity remains comparable to its 1980 levels and only slightly higher than in 1961. The Caribbean reached its peak productivity in 2013 but has since experienced a decline of 5% by 2021.

Notably, all subregions experience a short-lived period of positive TFP growth until 1980. In the mid-80s, Southern Cone countries advance rapidly and takes the lead with continuous TFP growth until mid-2010s. After that period, agricultural productivity growth has plateaued in all subregions.

Figure 2: Evolution of TFP (1961–2021) for the LAC Subregions



4.1.2 Output, TFP and Inputs Growth

Output Growth

Figure 3 maps each country's average annual agricultural output growth rates between 1961 and 2021, with darker shades indicating higher growth and lighter shades representing lower (sometimes negative) growth. Overall, output growth across countries in LAC has been uneven. In South America, for instance, Brazil, Bolivia, and Paraguay have experienced the highest average annual growth rates, at around 3.5%. Chile, Peru, and Ecuador's annual output growth rates are also around at 3%. In contrast, Guyana and Uruguay experienced the continent's slowest output growth rates, at 1.33% and 1.42%, respectively. Moving to Central America, Guatemala, Belize, Nicaragua, and

Costa Rica are the region's leaders in output growth, with levels comparable to those of South America's top performers. Conversely, the Caribbean region has presented the weakest performance over the last six decades. For instance, Trinidad and Tobago and Jamaica, experienced negative output growth rates. Haiti shows some positive but very modest output growth, at 0.88%.

Figure 3: Agricultural Output Annualized Average Growth Rate for the LAC Region (1961-2021)

TFP and Input Growth

As mentioned, output growth can be attributed to TFP growth and/or input growth. The following maps illustrate the performance of countries in terms of productivity growth and input growth, where input includes labor, land, capital, and materials. Figure 4 shows the TFP annual average growth rate between 2961 to 2021.TheLAC region exhibits a weaker performance in TFP growth, compared to output growth. Chile emerges as the leading performer in terms of TFP growth at 2.27%, followed by Brazil at 1.81% and Costa Rica at 1.61%. Mexico, Bahamas, and Bolivia also show strong productivity growth. Notably, three countries in the region experienced negative average annual TFP growth rates: Trinidad and Tobago (-1.24%), Suriname (-0.13%), and Guyana (-0.70%). Additionally, countries like Suriname, Jamaica, Uruguay, Haiti, El

Salvador, and Panama have TFP growth rates that are closely approaching zero. Table C.1 in Appendix C provides a detailed breakdown of growth decomposition for each country.

Figure 4: Agricultural Total Factor Productivity Annualized Average Growth Rate for the LAC Region (1961-2021)

Figure 5 displays input growth rates for each country while Figures 5A, 5B, 5C and 5D present the average annual growth rates for four input categories: capital, agricultural materials, labor, and land. Analyzing these figures in conjunction with the overall TFP and output growth trends allows for a more comprehensive examination of the factors influencing each country's output growth. When a country exhibits low productivity growth but high agricultural output growth, improvements are driven by growth in input use. This applies for countries like Paraguay and Belize, where the increase in output can be attributed primarily to the growth in inputs. Conversely, while all countries have seen positive average annual input growth rates, some have experienced low rates of less than 1%. Examples of countries with low input growth rates include Chile, El Salvador, Haiti, Jamaica, and Trinidad and Tobago.

Figure 5: Agricultural Input Annualized Average Growth Rate for the LAC Region (1961-2021)

In addition to analyzing the overall growth of inputs, we can also assess growth by input category.[5]

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[5] Table C.2 in Appendix C presents the annual average growth rate for each input across all countries and subregions in LAC.

Paraguay leads with an average annual land use growth rate exceeding 2.5%, followed by Belize, Peru, and Bolivia, each surpassing 1.7% (see Figure 5A). Brazil and Argentina, despite being top GDP performers in the region, show more modest increases of 1.33% and 1.16% respectively. Meanwhile, countries like Uruguay, Chile, Trinidad and Tobago, and Jamaica have shown negative growth for land use. This means that, on average, these countries reduced the amount of land allocated to agriculture between 1961 and 2021. Most other countries have exhibited positive values for land growth, albeit close to zero.

In terms of capital growth (see figure 5B), Belize, Honduras, Guyana, Bolivia, Panama, Nicaragua and Paraguay experienced higher growth rates reaching 3% to 4.3%. In contrast, El Salvador and Haiti have displayed the lowest capital growth rates in the region, falling below 1%. Meanwhile, Colombia, Argentina, and the Dominican Republic have demonstrated slightly better performance, with capital input growth rates just exceeding 1%.

Figures 5A and 5B: Agricultural Land and Capital Inputs Annualized Average Growth Rate for the LAC Region (1961-2021)

Land

Capital

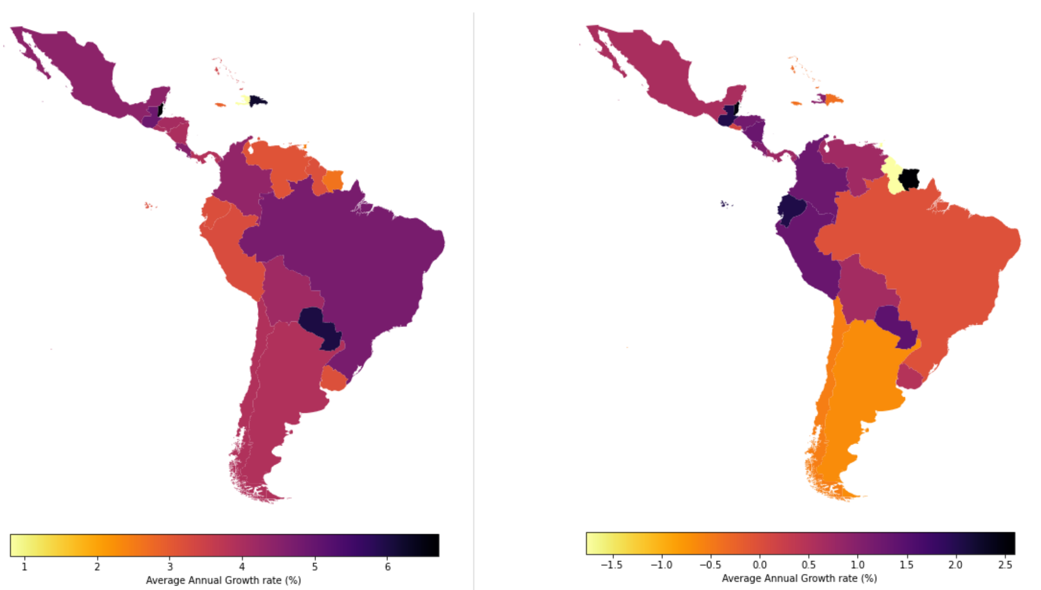
Figure 5C presents the growth rates of agricultural materials. For the region, the average growth rate of agricultural materials is 4.5%. Of all input categories, agricultural materials experienced the highest growth rates. The countries with the highest rates of growth for agricultural materials are Belize, with an average annual growth rate of nearly 7%, followed by Dominican Republic and

Paraguay with growth rates of over 6%. Costa Rica, Brazil and Guatemala have recorded growth rates over 4.5%. Most countries present robust growth in the use of agricultural material, with the exception of Haiti, which has grown by less than 1%.

In the realm of agricultural labor growth, Suriname and Belize have exhibited robust increases in agricultural labor, with annual growth rates surpassing 2.5%. Following closely behind, Ecuador and Guatemala have experienced growth rates exceeding 2%. However, labor input has demonstrated the least favorable performance among all four inputs across numerous countries, often presenting negative growth rates. Countries such as Chile, Argentina, Guyana, Trinidad and Tobago, Jamaica, the Dominican Republic, Brazil, and the Bahamas have shown slow to negative growth in agricultural labor, with average growth rates near or below zero.

Figures 5C and 5D: Agricultural Materials and Labor Inputs Annualized Average Growth Rate for the LAC Region (1961-2021)

Materials **Labor**



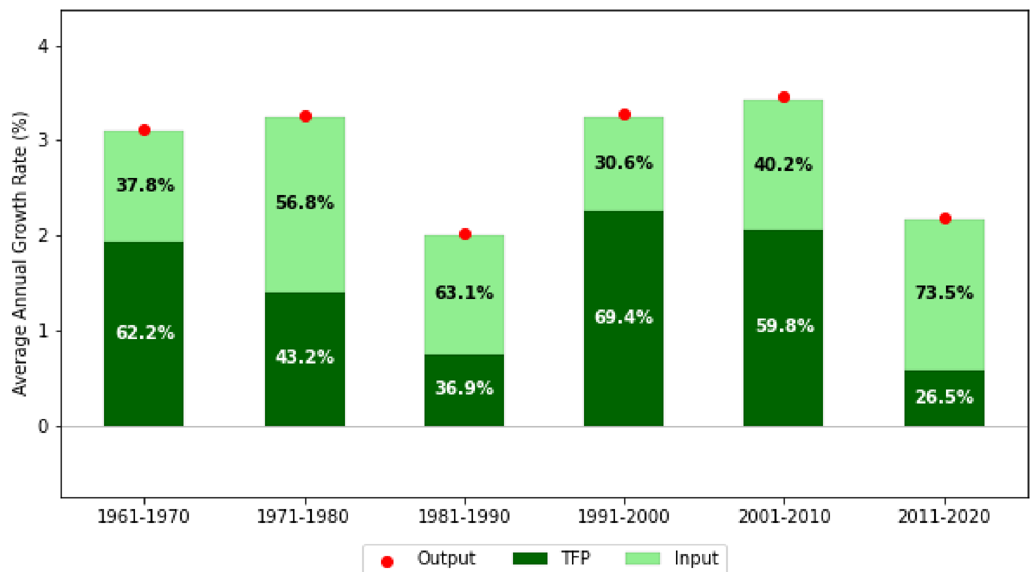
4.1.3 Trends in TFP Composition over time

Beginning the decomposition, we can also explore what is driving or constraining this output evolution in Latin America and the Caribbean.

4.1.3.1 LAC, by decade

Throughout the past six decades, the region maintained a steady average annual growth rate, with the 1980s and 2010s experiencing the lowest output growth at just over 2%. As shown in Figure 6, In LAC, the predominant factor driving agricultural production growth has historically been the increase in the use of inputs (land, labor, capital and materials). This trend held true until the 1990s and the 2000s, when productivity growth represented a more significant role. However, in the last decade (2011-2020) there has been a reversal in this pattern with a sharp decrease in TFP growth and a rise in input use, accounting for 75% of output growth. The most recent decade also presents the weakest output growth performance, with levels almost comparable to those seen in the "lost decade" of the 1980s. This confirms that agricultural productivity growth is facing a challenging time, highlighting potential setbacks for agricultural performance.

Figure 6: Agricultural Output Growth Decomposition for LAC



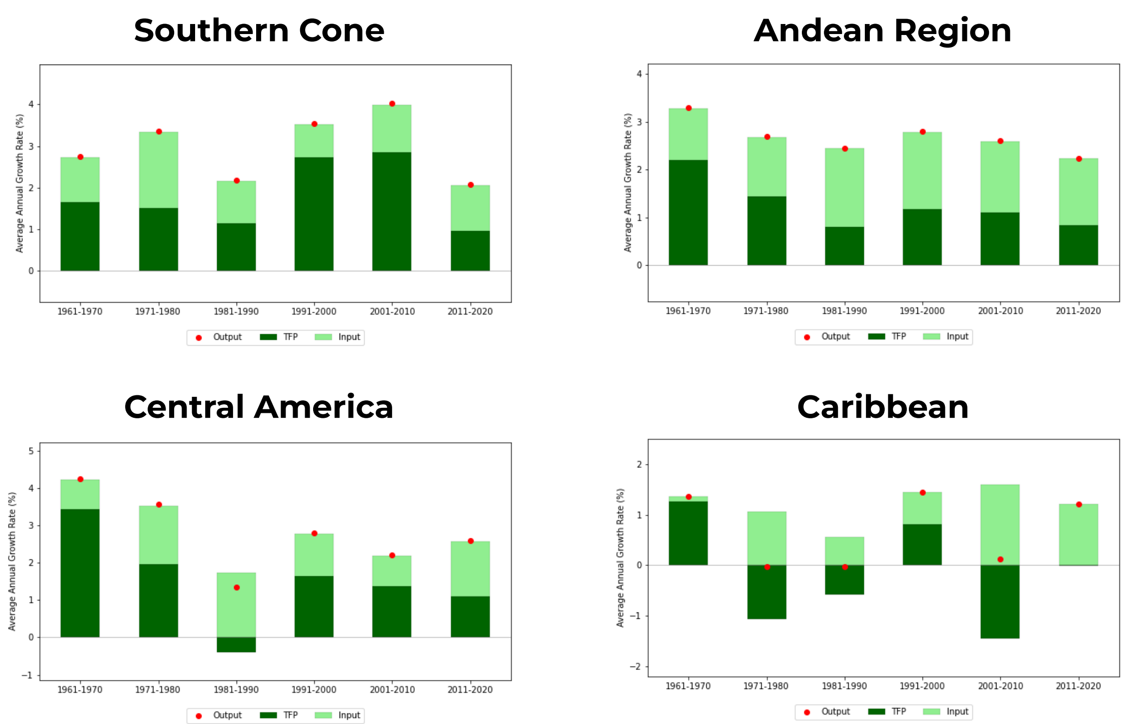
4.1.3.2 Subregions, by decade

When comparing the performance by subregions, we can analyze the different contributions of TFP and input use to output growth. Figure 7 illustrate the growth decomposition for each of LAC's four subregions. South America stands out for presenting consistent output growth. However, in the Southern Cone, output growth was primarily driven by TFP growth, while input growth is of greater significance in the Andean countries, especially in the last three decades.

The Central America region experienced a notable output growth decline of nearly 2% throughout the period and even experienced negative productivity growth in the 1980s. The TFP growth for this subregion has decreased steadily since the 2000s. Out of all subregions, the Caribbean experienced the most volatile productivity trends; this subregion experienced negative TFP growth rates in three decades, during the 1970s, the 1980s and the 2000s. In the most recent decade, output growth was just over 1% and this growth was driven almost entirely by growth in inputs use.

Evidently, decomposition at the subregional level reveals significant disparities across subregions. However, a common trend across subregions highlights the slowdown on productivity growth and the increasing reliability on input use to maintain agricultural output in the last decade.

Figure 7: Agricultural Output Growth Decomposition by Subregion



4.2 Resource Decomposition

We can further decompose inputs or $g(X_t)$, to examine the contribution of each input used in the agricultural production process. This accounting considers aggregate measures of four inputs: land, labor, capital and intermediate inputs:

$$g(Y_t) = g(TFP_t) + \sum_{j=1}^{4} S_{jt} g\left(X_{jt}\right) \qquad (4)$$

Where:

- $\mathrm{Y_t}$: total gross value of agricultural output, in thousands constant 2015 international dollars.
- $\mathrm{X_{1t}}$: quality-adjusted total agricultural land area (of rainfed equivalent cropland), in thousands of ha.
- $\mathrm{X_{2t}}$: total economically active adults primarily employed in agriculture, in thousands of persons.
- $\mathrm{X_{3t}}$: value of net capital stock, in thousands constant 2015 international dollars.
- $\mathrm{X_{4t}}$: index of crop and animal intermediate inputs, 2015=100.
- $\mathrm{S_{jt}}$: cost shares for land, labor, capital and materials, varying by decade.

Next, we use the cost decomposition equation to obtain a decomposition of output growth based on the growth of TFP, land expansion (agricultural extensification), and the increase in the use of inputs per unit of land (intensification):

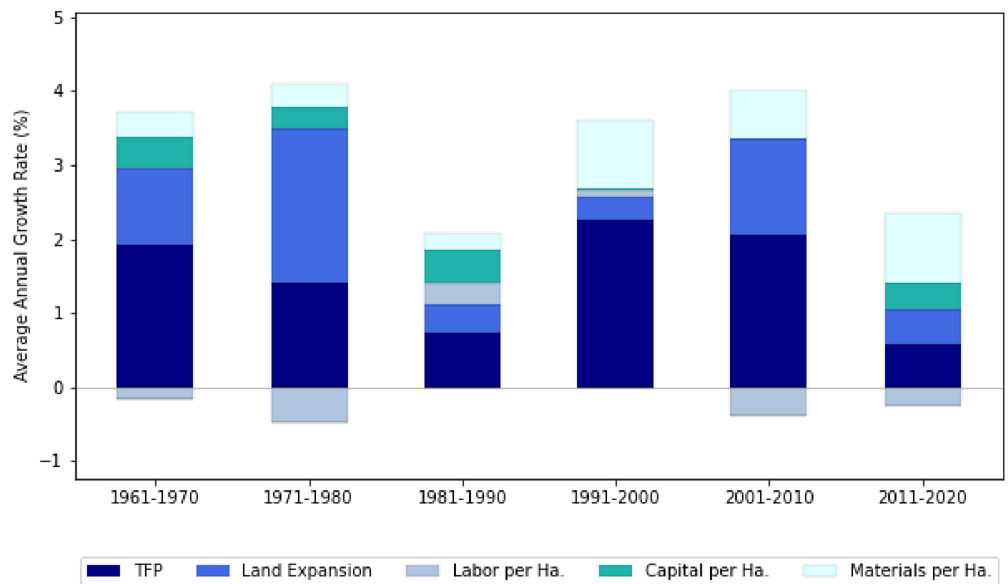
$$g(Y_t) = g(TFP_t) + g(X_{1t}) + \sum_{j=2}^{4} S_{jt} g\left(\frac{X_{jt}}{X_{1t}}\right) \qquad (5)$$

Resource decomposition focuses on the quantity change of a specific resource, rather than its contribution to changes in the cost of production.

4.2.1 LAC, by decade

Conducting a resource decomposition allows us to distinguish which factors contribute most to agricultural output growth: TFP growth, land extensification (expanding agricultural land) or input intensification (increasing the use of inputs per hectare). Figure 8 presents the evolution by decade for the LAC region. As presented in the previous section, TFP gains are a significant driver of output growth in the 1990s and 2000s. Though land expansion was the primary driver of output growth in the 1970s, its relative contribution has diminished since then. However, in the 2000s, land expansion gain importance again. In contrast, the intensification of agriculture through agricultural input materials (given by feed and fertilizers per HA) has played an increasingly important role in driving agricultural output growth since the 1970s and was the primary contributor in the most recent decade. Interestingly, capital inputs (which includes machinery and livestock) play a relatively minimal role in driving agricultural output growth. Also, notably, the contribution of labor is negative in every decade except for the 1980s and 1990s, however, its contribution to output growth has been rather small overall decades of analysis.

Figure 8: Resource Decomposition of Agricultural Output Growth for LAC

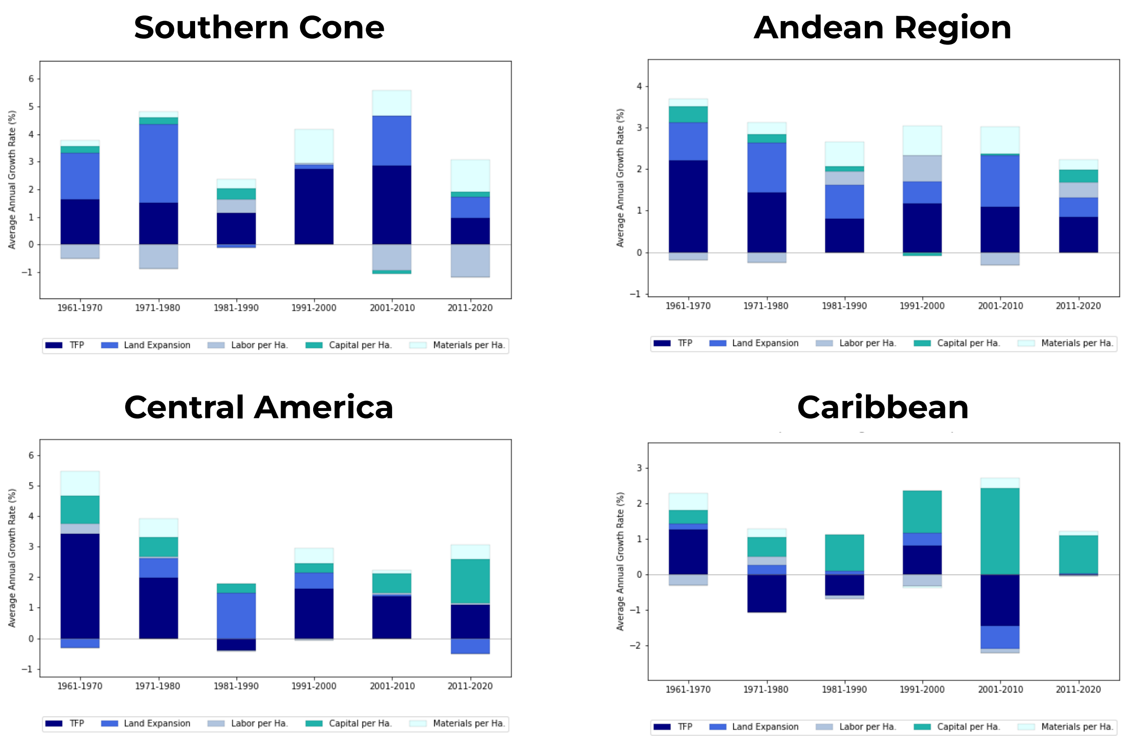


4.2.2 Subregions, by decade

This section applies the resource decomposition by subregions. For the Andean Region and Southern Cone, land expansion is generally the primary input driving output growth, though its contributions to growth play a smaller role than TFP. Meanwhile, capital intensification is the most significant contributor to input growth for the Caribbean and Central America. In Central America, increases in capital per Ha offset decelerating TFP gains in the last two decades. For the Caribbean, increases in capital intensification drive nearly all output growth in the last two decades, even offsetting significant losses in TFP, land, and labor in the first decade of the 2000s. Generally, intensification through input materials becomes a more significant contributor to growth for all four subregions, with a slight dip noted in the Caribbean and Central America regions during the 1980s and 1990s.

A significant concern arises from the pronounced decrease in labor input across all subregions, with some even showing negative growth. This trend is particularly evident in the Andean countries, the Caribbean, and the Southern Cone, with Central America being the only subregion that has not experienced negative growth rates in labor use. Furthermore, both the Caribbean and Central America regions have also witnessed negative growth rates in productivity and capital input, as mentioned earlier. It is apparent that land intensification is being driven by the growth of materials and capital inputs.

Figure 9: Resource Decomposition of Agricultural Output Growth by Subregion

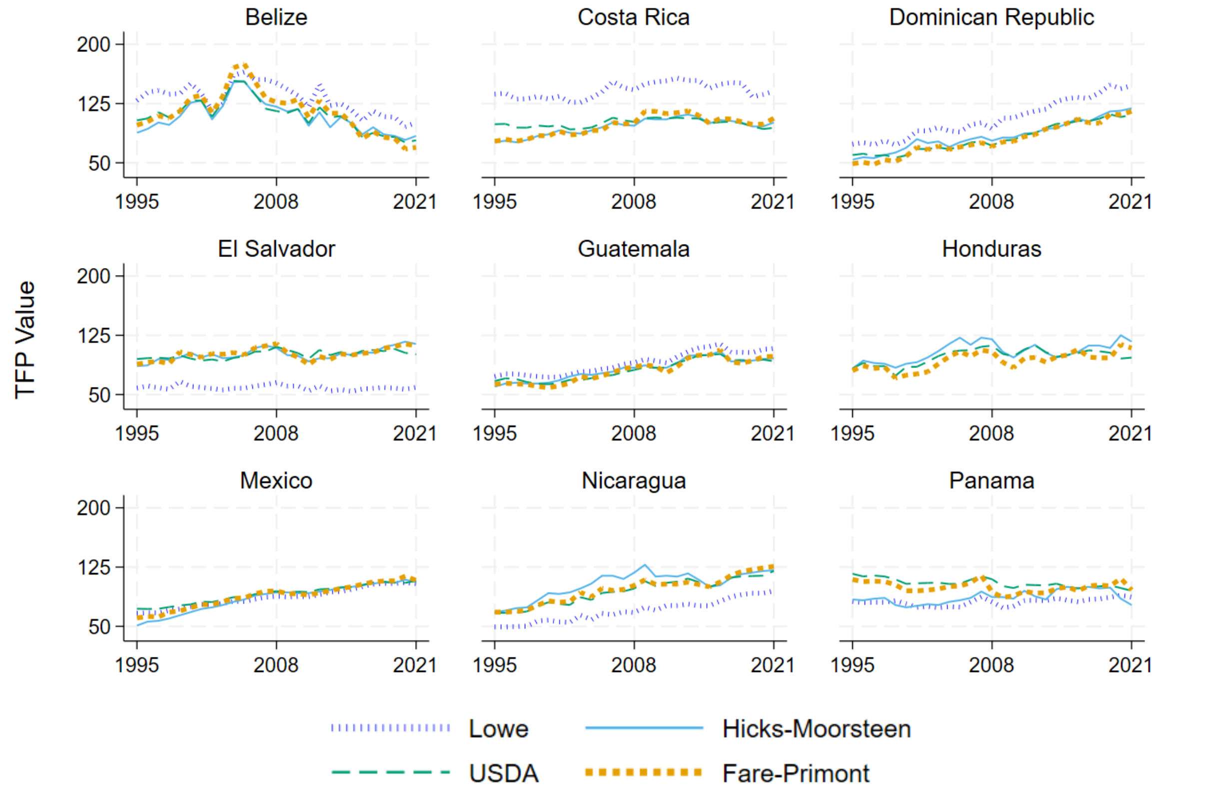


5. Measuring TFP: Multiple Indices

The analysis of Total Factor Productivity (TFP) trends across Latin American and Caribbean (LAC) countries reveal distinct regional and national productivity patterns, with notable differences among Central America, the Caribbean, the Southern Cone, and the Andean Group. This analysis uses four indices—Lowe, Hicks-Moorsteen, USDA, and Fare-Primont—to provide a comprehensive view of TFP trends. Each index offers unique insights due to its methodological differences, allowing us to capture both stable growth and dynamic shifts in productivity across the region.

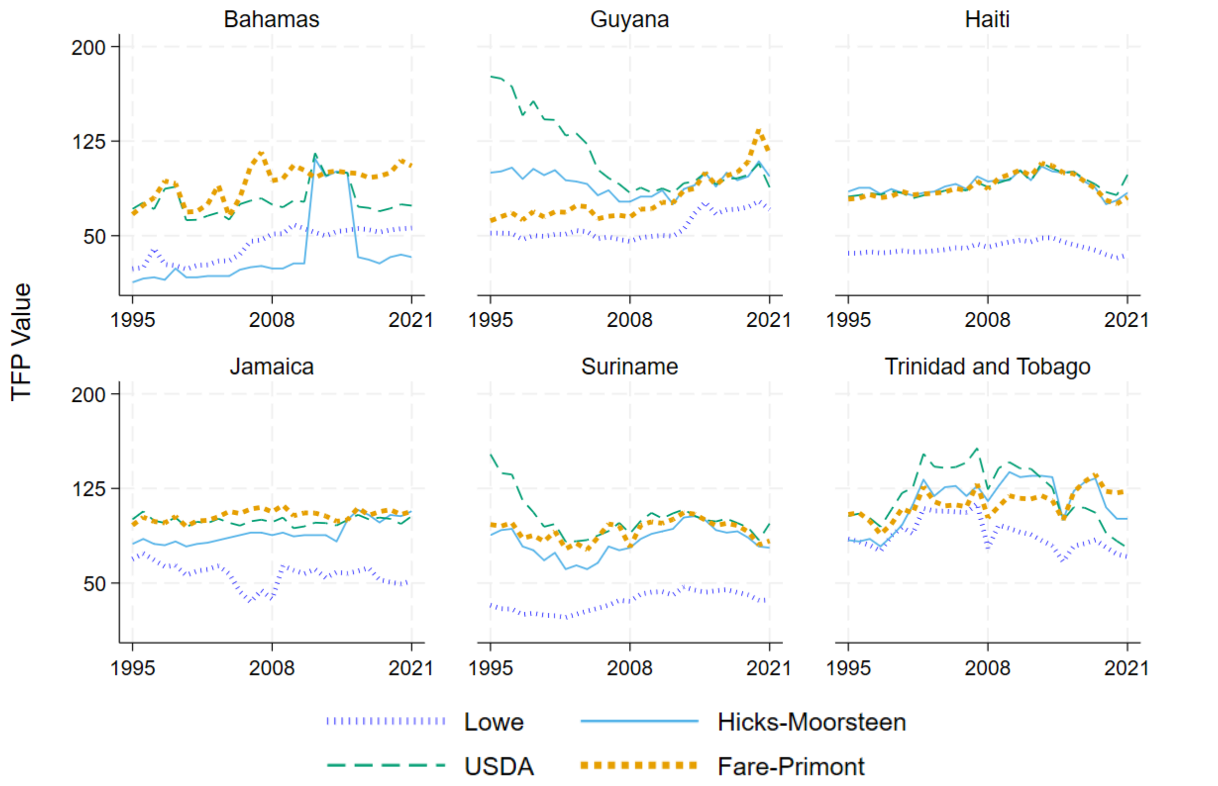
For the analysis, LAC countries have been analyzed by subregions: Central America, Caribbean, Southern Cone and Andean countries.

Figure 10: Trend Comparison of TFP Indices for Central American Countries (1995-2021)



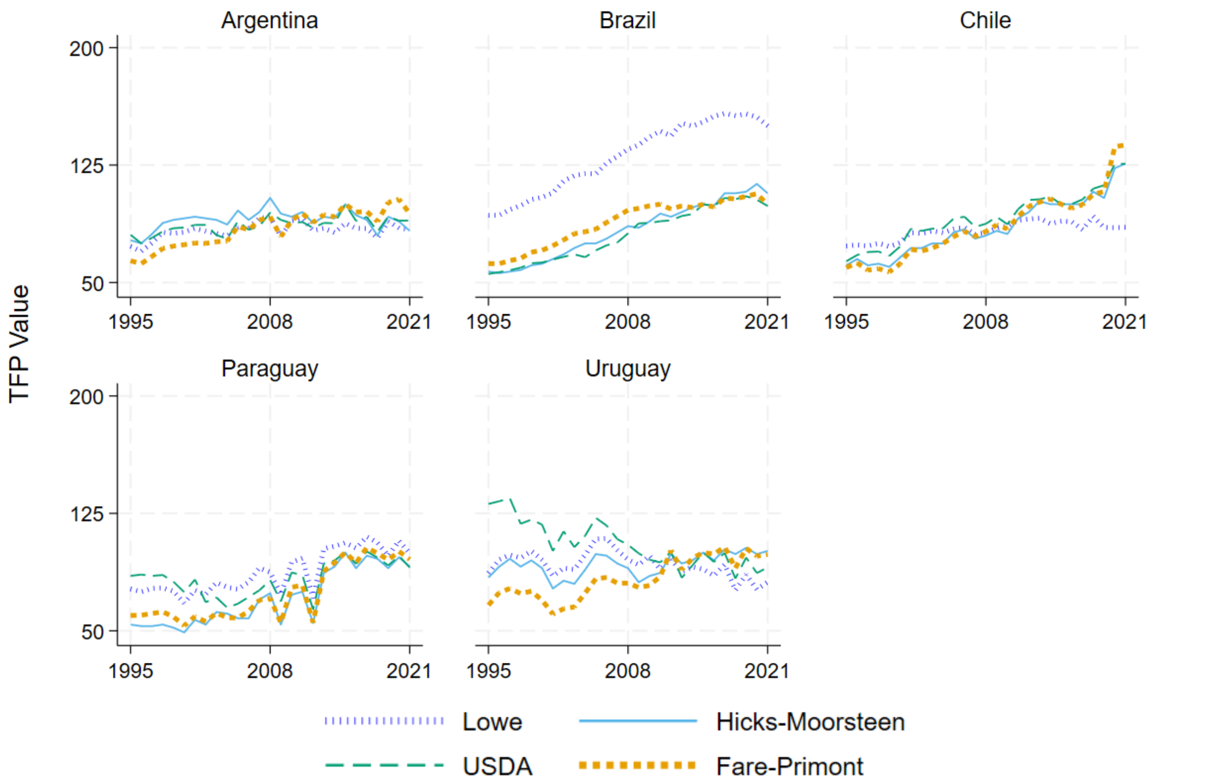
In Central America, countries generally exhibit stable TFP levels from 1995 to 2021. Dominican Republic, Guatemala, Mexico and Nicaragua show upward trends, particularly in the Hicks-Moorsteen and Fare-Primont indices, suggesting productivity improvements. In contrast, Costa Rica and El Salvador present e minimal productivity growth, indicating some potential stagnation while Belize portrays continuous TFP decline since the early 2000s. The conservative Lowe index reflects stable productivity across most countries, while indices with variable weights, such as Hicks-Moorsteen, are more sensitive to changes in economic conditions, providing a nuanced view of growth in Nicaragua and the Dominican Republic.

Figure 11: Trend Comparison of TFP Indices for Caribbean Countries (1995-2021)



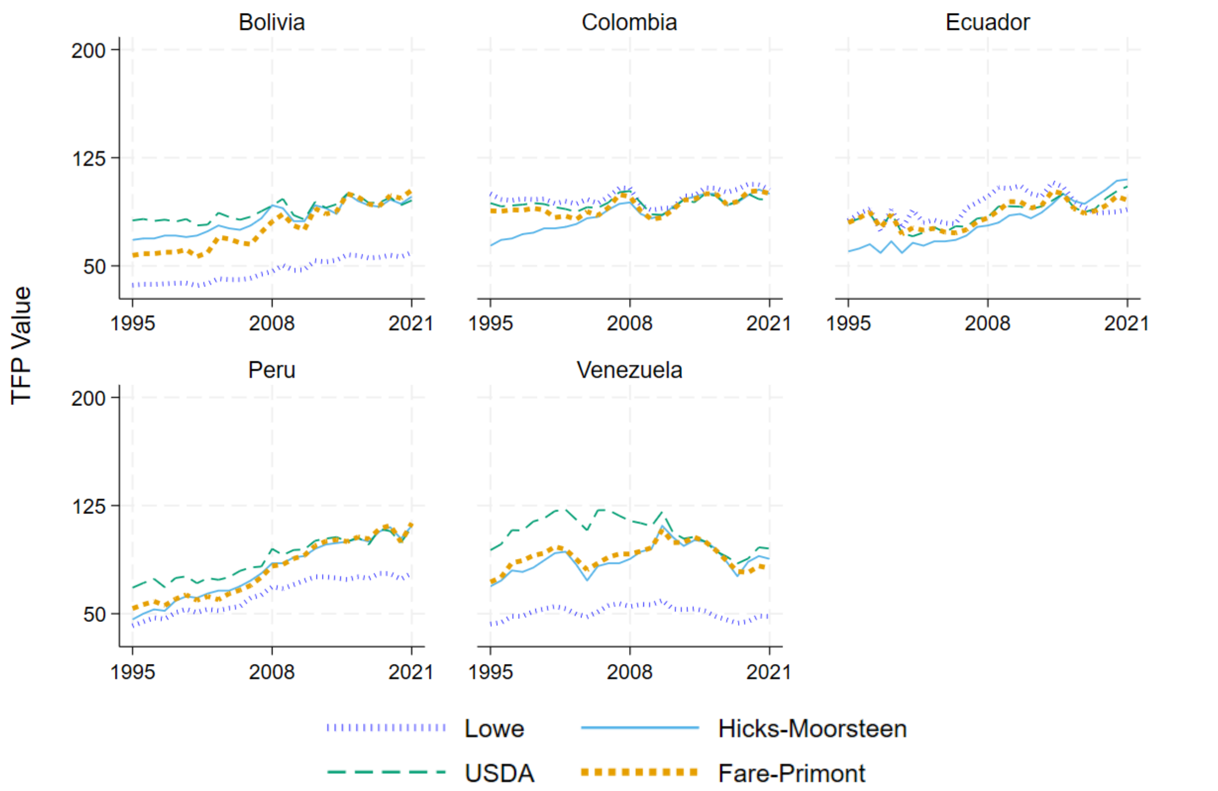
The Caribbean countries display high volatility in TFP trends. The Bahamas and Guyana show notable fluctuations, with USDA and Fare-Primont indices indicating higher productivity levels. In contrast, Haiti, Jamaica and Suriname maintain relatively stable TFP levels, while Trinidad and Tobago experience moderate fluctuations across all indices without major TFP increase. The variability among indices, particularly in more volatile economies, illustrates how variable-weight indices (e.g., Hicks-Moorsteen and USDA) can capture rapid changes, while fixed-weight indices (e.g., Lowe) tend to smooth out these shifts.

Figure 12: Trend Comparison of TFP Indices for Southern Cone Countries (1995-2021)



In the Southern Cone countries, the various TFP indices behave rather similarly particularly since 2008. Brazil and Chile exhibit strong upward TFP trends, reflecting significant productivity growth. The alignment among the indices highlights the robustness of this growth, as evidenced by both fixed and variable-weight methodologies. Since 2008, Paraguay has also shown a notable TFP increase, comparable to the trends observed in Brazil and Chile, while Argentina and Uruguay display relatively stable TFP values with only minor variations.

Figure 13: Trend Comparison of TFP Indices for Andean Countries (1995-2021)



The Andean Group shows mixed TFP trends, with countries like Colombia and Ecuador maintaining relatively stable TFP values, especially since 2008. On the other hand, Bolivia presents a modest but increasing TFP while Peru is the top performing country of this group, showing a steady upward trend, especially in the Fare-Primont and USDA indices, signaling ongoing productivity gains. Finally, particularly in the last two decades, Venezuela exhibits negative TFP growth overtime.

Each of the four indices bring unique strengths to the TFP analysis. The Lowe index, with fixed prices, provides a stable, long-term perspective on productivity, often showing conservative trends in volatile economies. The Hicks-Moorsteen and USDA indices, which incorporate variable weights, are more responsive to economic shifts and are particularly useful in regions with significant economic fluctuations. Meanwhile, the Fare-Primont index captures changes driven by efficiency gains, aligning with growth trends in countries experiencing structural transformations, like Peru.

In summary, the combination of indices provides a nuanced understanding of TFP trends across LAC. While stable economies like Brazil and Chile exhibit consistent productivity growth across all indices, volatile or changing economies benefit from indices that adapt to shifts in prices and quantities. This analysis highlights both steady growth and dynamic shifts, demonstrating how methodological choices influence productivity assessments and insights in diverse economic contexts across the LAC region. There is no single "correct" choice of index; the optimal index depends on the specific context and the period of analysis. However, to better appreciate TFP dynamics across regions and countries it is useful to compare the performance of various indices to present a more complete unbiased context.

6. Conclusions

Productivity has been a pivotal for agricultural output over the past six decades. However, TFP growth has not been consistent over time, with distinct periods of notable increases and declines. From 1961 to 1980 and from 1991 to 2010, the LAC region experienced significant TFP growth. Conversely, the 1980s, often referred to as LAC's "lost decade", resulted on a negative impact on agricultural production and TFP levels. In the most recent decade of our analysis, a concerning trend emerges: TFP and output growth levels in the 2010s have declined to even lower levels than those seen during the 1980s, indicating a possible downturn in agricultural productivity.

The cross-country comparisons facilitated by the study's data and methodology highlight various disparities. In fact, this analysis confirms the large heterogeneity that exists among countries in the region, emphasizing the importance of implementing policies tailored to different regions' and countries' needs and resources. However, a general trend across all subregions is the decline in agricultural output growth during the 2010s, which has been accompanied by a decrease in all its contributing factors, namely productivity (measured by TFP) and input use. Furthermore, in the last decade, all subregions have increased reliance on input use for agricultural production rather than boosting TFP growth. Addressing this trend is essential to ensure long-term sustainability and to mitigate potential challenges such as environmental impacts, biodiversity loss, and soil degradation, which could otherwise influence agricultural productivity over time.

To sum up, as climate change exacerbates productivity losses and food insecurity, it is crucial to enhance agricultural productivity sustainably without further expanding land use or relying on inputs that damage natural resources. This study provides an initial assessment with a comprehensive overview of agricultural output and productivity trends for LAC countries from 1961 to 2021. However, to prioritize effective policies that result on sustainable productivity gains, is of outmost importance to conduct detailed analyses at the national and subnational levels to identify potential drivers of agricultural productivity growth, ensuring environmental sustainability and improving livelihoods of the most vulnerable populations.

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Appendix A. Measurement of TFP growth using the Index Number Theory Approach

The TFP growth rate of a unit that produces M outputs using N inputs can be defined as the ratio between output and input quantity indexes:

$$TFPG = Y(p_t, p_0, Y_t, Y_0)/X(w_t, w_0, X_t, X_0) \qquad (A.1)$$

Where $p_t = [p_t^1 \dots p_t^M]$ and $w_t = [w_t^1 \dots w_t^N]$ are output and input price vectors for period t. Similarly, output and input quantity vectors are defined as follows: $Y_t = [Y_t^1 \dots Y_t^M]$ and $X_t = [X_t^1 \dots X_t^M]$. Thus, these quantity indexes are defined as functions of output and input prices and quantities for a particular period t and a base period 0.

One of the most frequently used functional forms for quantity indexes is the Laspeyres index. In this specification, the output quantity index is defined as the ratio between the value of production in period t using output prices from the base period 0, and the value of production at the base period.

$$Y(p_t, p_0, Y_t, Y_0) = \sum_{m=1}^{M} p_0^m Y_t^m \Bigg/ \sum_{m=1}^{M} p_0^m Y_0^m \qquad (A.2)$$

After rearranging terms, we could express $Y(p_t, p_0, y_t, y_0)$ as the sum of M output quantity ratios, weighted by the base period revenue share of each output m:

$$Y(p_t, p_0, Y_t, Y_0) = \sum_{m=1}^{M} \left(\frac{Y_t^m}{Y_0^m}\right) R_0^m \qquad (A.3)$$

Where the revenue share for output m us defined as $R_t^m = p_t^m Y_t^m / \sum_{m=1}^{M} p_t^m Y_t^m$. Similarly, the input quantity index can be expressed as base period cost share weighted sum of N input quantity ratios:

$$X(w_t, w_0, X_t, X_0) = \sum_{n=1}^{N} w_0^n X_t^n \Bigg/ \sum_{n=1}^{N} w_0^n X_0^n = \sum_{n=1}^{N} \left(\frac{X_t^n}{X_0^n}\right) S_0^n \qquad (A.4)$$

Where $S_t^n = w_t^n x_t^n / \sum_{n=1}^{N} w_t^n x_t^n$ is the cost share of input n in period t. According to Fuglie (2011), in a competitive market setting in which producers are price takers for inputs and outputs, they will use inputs up to the point where the value of the marginal product of such input equals their price (we drop time subscript for simplicity) [6]:

$$P \cdot PMg_{Y,X^n} = w^n \qquad (A.5)$$

Since the constant returns-to-scale assumption implies that total revenues equal total costs (e.g.: $PY = \sum_{n=1}^{N} w_t^n x_t^n$), if we define the marginal product of input n as $PMg_{Y,X^n} = \partial Y / \partial X^n$ and multiply both terms of Eq. X by the expression X^n / Y, we obtain that the output-input elasticity of input n equals its cost share:

$$\epsilon_n = \frac{w^n X^n}{PY} = S^n \qquad (A.6)$$

Where the output elasticity of input n is defined as $\epsilon_n = \frac{\partial Y}{\partial X^n} \frac{X^n}{Y}$. Furthermore, the constant returns-to-scale assumption assures that the following two restrictions on cost shares hold:

$$\sum_{n=1}^{N} S^n = 1 \qquad (A.7)$$

$$0 \leq S^n \leq 1 \qquad (A.8)$$

[6] In a multi-product production process, we could consider Y as the aggregate output index and P as an aggregate output price index.

Appendix B. Aggregated regions

According to ERS USDA IAP Data Product, the Latin America and Caribbean region is subdivided into five subregions: Central America, Caribbean, Andes, Southern Cone, and Brazil. For study purposes, these subregions have been reconfigured to represent the Inter-American Development Bank's official subregional country groupings and include only IDB member states. Table B.1 presents the old subregions while Table B.2 presents the new aggregated subregions.

Table B.1

Central America	Caribbean	Andes	Southern Cone	Brazil
Belize	Bahamas	Bolivia	Argentina	Brazil
Costa Rica	Cuba	Colombia	Chile	
El Salvador	Dominican Republic	Ecuador	Paraguay	
Guatemala	Haiti	Peru	Uruguay	
Honduras	Jamaica			
Mexico	Puerto Rico			
Nicaragua	Trinidad and Tobago			
Panama	Lesser Antilles *			
	French Guiana			
	Guyana			
	Suriname			
	Venezuela			

Table B.2

Central America (CID)	Caribbean (CCB)	Andean Group (CAN)	Southern Cone (CSC)
Belize	Bahamas	Bolivia	Argentina
Costa Rica	Guyana	Colombia	Brazil
Dominican Republic	Jamaica	Ecuador	Chile
El Salvador	Suriname	Peru	Paraguay
Guatemala	Trinidad and Tobago	Venezuela	Uruguay
Haiti			

Honduras Mexico Nicaragua Panama			

Barbados is the only IDB member state not included in the new aggregated subregions, as in the USDA productivity analysis division, it is included in the Lesser Antilles with other minor islands and does not have country-specific data. With only that state excluded, we have recalculated quantities for variables such as quality-adjusted land, capital, labor, fertilizer, and feed for the new aggregated subregions. With these new total amounts, we can calculate the new indexes for each input and for each subregion. Cost shares remain the same for all countries except for Venezuela, which was previously part of the Caribbean but now assumes share values estimated for the Andean Group.

Appendix C: Annual Average Growth Rate 1961-2021 (%)

Table C.1

Country	Output	TFP	Input
Argentina	2.01	0.88	1.12
Bahamas	2.27	0.77	1.49
Belize	3.36	0.74	2.60
Bolivia	3.56	1.41	2.12
Brazil	3.48	1.81	1.64
Chile	2.98	2.27	0.69
Colombia	2.35	0.90	1.44
Costa Rica	3.33	1.61	1.70
Dominican Republic	2.12	0.78	1.33
Ecuador	3.04	0.90	2.12
El Salvador	1.18	0.37	0.81
Guatemala	3.63	1.61	1.99
Guyana	1.33	-0.70	2.04
Haiti	0.88	0.43	0.45
Honduras	2.72	0.66	2.05
Jamaica	0.74	0.12	0.61
Mexico	2.89	1.31	1.56
Nicaragua	3.01	0.74	2.25
Panama	1.96	0.00	1.96
Paraguay	3.60	0.39	3.20
Peru	3.01	0.97	2.02
Suriname	1.94	-0.13	2.08
Trinidad and Tobago	-0.50	-1.24	0.74
Uruguay	1.42	0.08	1.34
Venezuela	2.02	1.78	0.22
Andean Group	2.70	1.44	1.24
Caribbean	0.87	0.58	0.29
Central America	2.78	1.77	0.99
Southern Cone	2.98	2.09	0.88
LAC, Total	2.89	1.72	1.15

Table C.2

Country	Capital	Labor	Land	Materials
Argentina	1.15	-0.66	1.16	3.92
Bahamas	2.78	-0.33	0.43	3.48
Belize	3.01	2.51	1.93	6.71
Bolivia	3.22	0.68	1.73	4.19
Brazil	2.34	-0.03	1.33	4.73
Chile	1.68	-0.52	-0.83	3.92
Colombia	1.00	1.28	0.09	4.36
Costa Rica	2.33	1.05	0.59	4.56
Dominican Republic	1.19	-0.37	0.48	6.23
Ecuador	2.84	2.06	0.54	3.22
El Salvador	0.69	0.13	0.51	4.03
Guatemala	2.25	2.04	1.06	4.93
Guyana	3.78	-1.75	0.37	3.18
Haiti	0.69	0.96	0.24	0.81
Honduras	3.65	1.20	0.18	4.10
Jamaica	1.27	-0.39	-0.55	2.90
Mexico	2.34	0.61	0.28	4.46
Nicaragua	4.17	1.31	0.79	4.00
Panama	4.30	0.74	0.34	3.87
Paraguay	3.35	1.42	2.62	6.03
Peru	1.62	1.30	1.79	3.27
Suriname	2.46	2.60	1.40	2.64
Trinidad and Tobago	2.36	-1.77	-0.98	2.47
Uruguay	2.33	0.49	-0.16	3.18
Venezuela	2.22	0.71	0.17	3.13
Andean Group	1.75	1.26	0.85	3.80
Caribbean	2.42	-0.65	0.08	1.90
Central America	2.24	0.83	0.36	3.96
Southern Cone	1.82	-0.10	1.16	4.64
LAC, Total	1.89	0.60	0.92	4.47

Appendix D: Agricultural TFP Annual Average Growth Rate per decade (%)

Table D.1

Country	1960	1970	1980	1990	2000	2010
Argentina	1.04	2.91	0.11	1.07	0.14	0.11
Bahamas	2.66	2.61	-1.42	-0.68	2.45	-0.30
Belize	1.71	2.97	0.17	6.14	-0.93	-3.04
Bolivia	2.90	2.83	1.68	1.04	0.97	1.28
Brazil	0.93	0.35	1.50	2.48	3.48	1.60
Chile	1.32	1.26	1.68	4.11	0.39	2.93
Colombia	1.67	2.29	0.45	0.61	-0.63	1.35
Costa Rica	4.17	1.13	3.22	1.04	1.05	-1.50
Dominican Republic	0.05	-0.40	-1.83	0.56	1.75	2.62
Ecuador	0.58	0.61	2.00	0.07	2.91	1.24
El Salvador	0.80	1.36	-0.44	-0.17	1.09	0.83
Guatemala	2.75	2.08	1.43	0.35	2.90	1.28
Guyana	-0.28	-0.65	-3.16	2.08	-5.61	2.28
Haiti	0.62	1.55	-0.29	-0.55	1.94	-2.34
Honduras	2.10	0.01	-0.73	1.04	1.64	-1.26
Jamaica	0.42	-2.07	1.42	0.40	-0.59	0.23
Mexico	2.80	2.24	-1.92	2.30	1.63	1.32
Nicaragua	3.35	-4.14	-3.07	2.26	2.85	0.92
Panama	1.89	-0.43	1.31	-2.07	-0.65	-0.46
Paraguay	1.59	-0.23	1.71	-1.80	0.59	1.50
Peru	1.39	-2.38	0.54	1.77	3.17	0.55

Suriname	4.14	2.70	-3.30	-5.69	0.97	-2.04
Trinidad and Tobago	0.28	-2.48	-0.51	2.14	1.67	-5.66
Uruguay	3.67	0.97	0.21	-0.93	-0.63	-0.83
Venezuela	4.78	3.35	0.08	2.64	-0.34	-2.77