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After the boom: Agriculture in Latin America and the Caribbean

Environment, Rural Development and Risk Management Division

Alejandro Nin-Pratt
Héctor Valdés Conroy

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Keywords: agriculture, efficiency, GHG emissions, Latin America, Caribbean, technical change, total factor productivity

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Abstract

The convergence of a favorable macroeconomic environment and high prices of primary commodities between 2000 and 2011 contributed to the best performance of agriculture in Latin America and the Caribbean (LAC) since the 1980s, with steady growth of total factor productivity (TFP) and output per worker and a reduction in the use of input per worker. The end of the upward phase of the commodity cycle in 2011 together with less favorable external markets and a deterioration of the policy environment in several countries, motivates us to revisit the situation of agriculture in LAC in recent years to analyze how these changes have affected its performance. This study applies a framework that uses index numbers together with data envelopment analysis (DEA) to estimate levels of productivity and efficiency, incorporating technical change together with technical (TE) and environmental efficiency (EE) into the decomposition of TFP. The EE index adjusts the TFP measure for pollution, treating GHG emissions as a by-product of the desired crop or livestock outputs. TFP and efficiency of crop and livestock sub-sectors was calculated for 24 LAC countries from 2000 to 2016. Our results show that the period of fast agricultural growth in LAC, driven by technical change and resource reallocation, transformed agriculture in the region leaving it in a better position to cope with the more unfavorable regional macroeconomic environment and the less dynamic global markets observed after 2011.

Keywords: agriculture, efficiency, GHG emissions, Latin America, Caribbean, technical change, total factor productivity

Acronyms

DEA	Data Envelopment Analysis
EE	Environmental efficiency
GDP	Gross Domestic Product
GHG	Greenhouse gas
IDA	International Development Asociation
LAC	Latin America and the Caribbean
TE	Technical efficiency
TFP	Total Factor Productivity

1. Introduction

A 2015 study (Nin-Pratt et al. 2015), looking at the performance of Latin America and the Caribbean's (LAC) agriculture between 1981 and 2012, concluded that the convergence of a favorable macroeconomic environment and high prices of primary commodities contributed to the best performance of the sector of the last 30 years, with steady growth of total factor productivity (TFP), output and input per worker, and a reduction of the TFP gap between the region and OECD countries. The end of the upward phase of the commodity cycle in 2011, the less favorable external markets and a deterioration of the policy environment in several countries, motivates us to revisit the situation of agriculture in LAC in recent years to analyze how these changes have affected its performance.

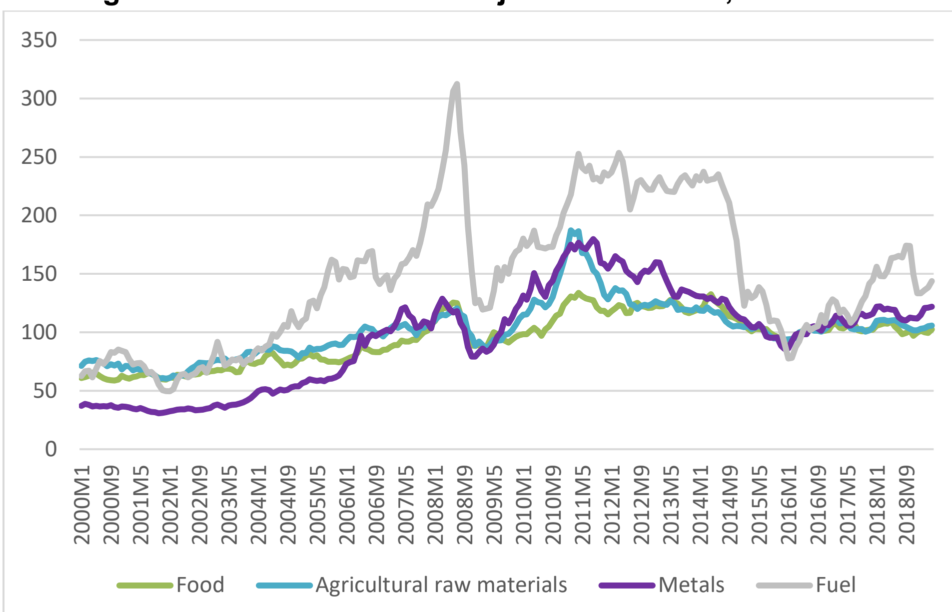
The goal of this report is to look at how changes in the economic environment after the global crisis of 2008, affected the performance of LAC's agriculture. To evaluate performance, this study applies the framework developed by O'Donnell (2017) that uses index numbers together with data envelopment analysis (DEA) to estimate TFP and to decompose changes in productivity into measures of technical change (measuring movements in the production frontier); and measures of efficiency change (movements towards or away from the frontier). A comprehensive measure of efficiency is built by incorporating technical (TE) and environmental efficiency (EE) in the decomposition of TFP mentioned above. The EE index adjusts the TFP measure for pollution, treating GHG emissions as a by-product of the desired crop or livestock outputs. TFP for crop and livestock sub-sectors was calculated for 24 LAC countries based on gross output from 2000 to 2016, using data from USDA-ERS (2019) and FAO (2019). Inputs from USDA-ERS database are allocated to crops (fertilizer, cropland, machinery) and livestock (feed, animal stock, pasture). The proportional method described in Lips (2017) is used to allocate total agricultural labor to crop and livestock production.

The paper is organized as follows. In the next section we present a short overview of the major changes in the economic environment in the region as a background to the empirical work. Section 3 presents the conceptual framework used for the analysis, complemented by a more detailed discussion of this framework in Appendix I. Sections 4 and 5 analyze the evolution of production, productivity and efficiency in agriculture and in the crop and livestock subsectors since 2000, comparing the favorable period that goes from 2000 to 2011, to the most recent years for which information is available. The last section concludes.

2. A changing environment

The context of the agricultural growth boom of the 2000s in LAC has changed significantly since the 2008 global economic crisis. Gruss (2014) argues that the upward phase of the commodity cycle that started in the early 2000s was over by 2011, with commodity prices falling or remaining stable, reflecting an anticipated increase in commodity supply along with weaker demand from China and other major commodity-importing economies. The evolution of some of the relevant commodity prices for the region are displayed in Figure 2.1. Prices peaked in 2011 and remained high and stable until 2014, falling significantly in recent years.

Figure 2.1–Price indices of major commodities, 2000-2018.



Source: Produced by authors based on IMF (2019).

At the time Gruss (2014) wrote his paper, the economy was expected to slow down considerably because the region is highly dependent on commodities and has greatly benefited from the commodity boom. Gruss (2014) claimed that even though commodity prices were still higher than in the mid-2000s, and much higher than in the 1990s:

> *"…growth in the years ahead for the average commodity exporter in the region could be significantly lower than during the commodity boom, even if commodity prices were to remain stable at their current still-high levels. Slower-than-expected*

growth in China represents a key downside risk. The results caution against trying to offset the current economic slowdown with demand-side stimulus and underscore the need for ambitious structural reforms to secure strong growth over the medium term."

Gruss' (2014) expectations were confirmed, and what we observe at present is sluggish growth and recession in several countries, not only because of lower commodity prices, but also because of macroeconomic problems and policy readjustments. For example, Diniz (2016) argues that during the 2000s, economies in LAC saw a decade of falling debt-to-GDP ratios, having benefited from low international interest rates and high commodity prices. Because of these favorable conditions, most of Latin American economies used countercyclical fiscal policy to smooth out the effects of the 2008 recession and were able to keep stable indebtedness until 2011. However, according to Diniz (2016),

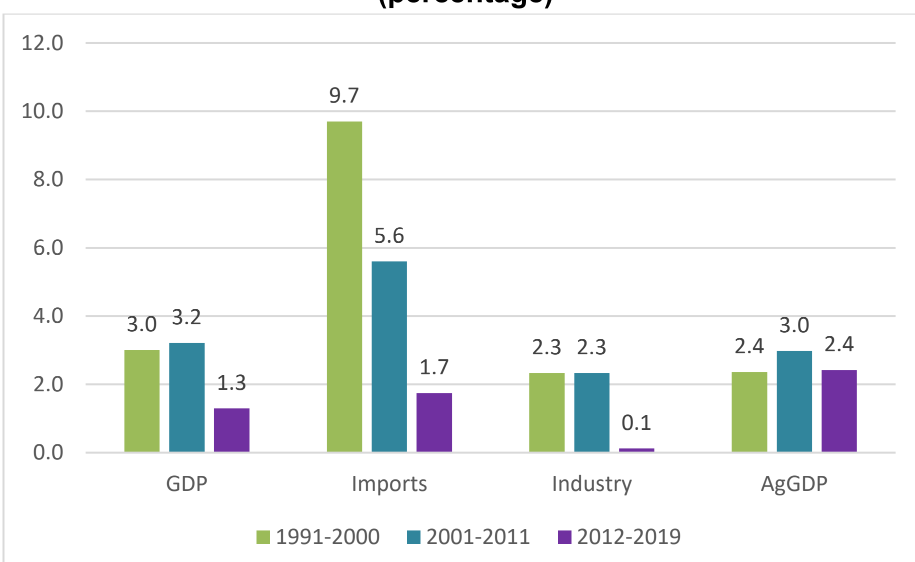
> *"…the shy recovery of the world economy since the crisis, together with China's slowdown and the end of commodity boom, Fed's departure from zero lower bound and a high degree of fiscal profligacy in some countries are some reasons why fiscal deficits reappeared and costs of servicing debt increased, … with average debt-to-GDP in the region at the end of 2014 returning to 2005 levels."*

Worsening of fiscal conditions and a persistent increase in debt-ratios brought back fiscal adjustments and recessions to the region. Figures 2.2 and 2.3 show growth rates of agricultural GDP (AgGDP) compared to growth in GDP and to other indicators frequently used in the literature as reliable measures of fluctuations in economic activity (Fernald, Gerstein and Spiegel 2019). For example, changes in imports of goods and services reflect both the use of intermediate inputs for production as well as finished goods imported for final consumption and seems to co-move very closely with GDP in the region. Industrial GDP captures activity on a specific area of the economy and is directly related to fluctuations in GDP, the broadest measure of economic activity.

All indicators of activity in Figure 2.2 show a clear slowdown of economic activity after

2011, which seems to capture the changes in economic environment and performance discussed by Gruss (2014). Growth in GDP fell from 3.2 percent in 2001-2011 to 1.3 on average between 2012 and 2019. Similarly, growth of imports of goods and services dropped from 5.6 percent on average between 2000 and 2011, to 1.7 percent during 2012-2019 while industry went from 2.3 to 0.1 percent growth in 2001-2011 and 2012-2019, respectively. In this context, agriculture seems to have been less affected by the economic environment after 2011, going from 3.0 percent in 2001-2011 to 2.4 percent in 2012-2019. Annual growth rates between 2000 and 2019 in Figure 2.3 clearly show the effect of the global crisis of 2008 on economic activity in LAC and the bouncing back to growth in 2010. But the end of the commodity price boom and the deterioration of economic conditions after 2010 brought high growth volatility and the end to the period of stable growth that started in 2003.

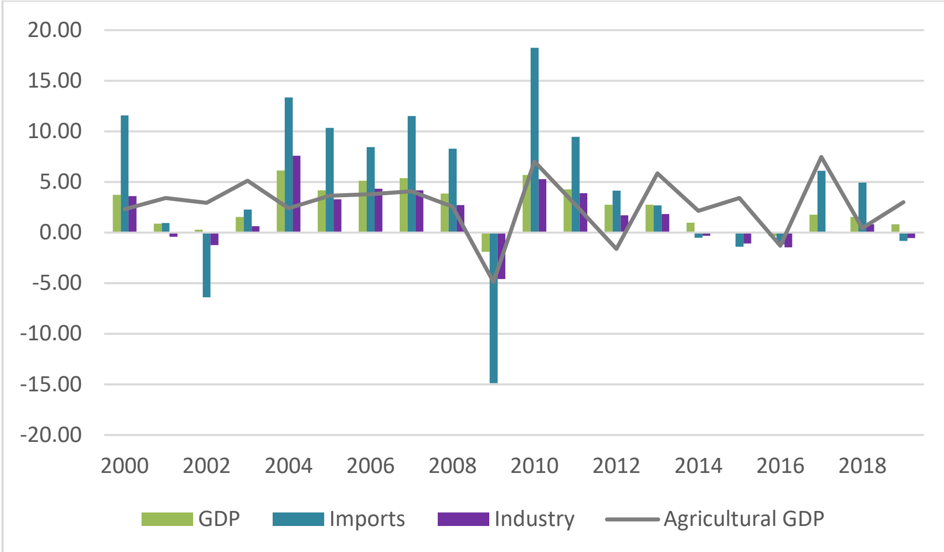
Figure 2.2–Average annual growth rates of economic activity for LAC in different periods (percentage)



Source: Produced by authors based on World Bank (2020).
Notes: GDP (constant 2010 US$); Imports=Imports of goods and services (constant 2010 US$); Industry=Industry (including construction), value added (constant 2010 US$); AgGDP=Agriculture, forestry, and fishing, value added (constant 2010 US$).

Figure 2.3–Average annual growth rates of economic activity for LAC, 2000-2018

(percentage)



Source: Produced by authors based on World Bank (2020).

Notes: GDP (constant 2010 US$); Imports=Imports of goods and services (constant 2010 US$); Industry=Industry (including construction), value added (constant 2010 US$); AgGDP=Agriculture, forestry, and fishing, value added (constant 2010 US$).

3. Conceptual framework

The study applies the framework developed by O'Donnell (2017) that uses index numbers together with data envelopment analysis (DEA)[1] to estimate levels of productivity and efficiency and to decompose changes in productivity into measures of technical change (measuring movements in the production frontier) and measures of technical efficiency change (movements towards or away from the frontier).

Total Factor Productivity (TFP) of a multiple-output multiple-input production unit is defined as the ratio of an index of aggregated output (Y) to an index of aggregated or total input (V):

$$TFP = Y/V \tag{3.1}$$

Following O'Donnell (2009), we aggregate outputs and inputs using pre-determined country and time-invariant reference weights. Details on how these weights were defined can be found in Appendix I. Pollution in the form of greenhouse gas (GHG) emission is introduced as one of the outputs of the production process represented in Figures AI.1 and AI.2 in the Appendix. A comprehensive index of performance of the agricultural sector is built by incorporating an environmental efficiency (EE) index in the decomposition of TFP efficiency. The EE index adjusts the TFP measure for pollution, treating GHG emissions as a by-product of the desired outputs. Desired outputs and pollutants are assumed to be the result of two separate production processes, where pollutants are produced by the polluting inputs (fertilizer, feed, animal stock) used in the production of the desired outputs. The intended-production technology is defined as a standard technology that describes how inputs are transformed into outputs and it is represented in the technical efficiency problem in Figure 3.1A. The pollution-generating technology is defined following the approach developed by Murty, Russell and Levkoff (2012) and is depicted in Figure 3.1B. This technology determines the relationship between pollution (an

[1] DEA is a 'mathematical programming model applied to observational data that provides a new way of obtaining empirical estimates of relations - such as the production functions and/or efficient production possibility surfaces – that are cornerstones of modern economies' (Charnes, Cooper, and Rhodes 1978).

output) and commodities used in the intended-production technology, where there is a minimal amount of pollution that can be by-produced by the technology given fixed levels of some inputs and/or of some intended outputs. The intended-production technology in Figure 3.1A is defined by two production units producing a desired output (*Y*) using one input (*V*). Unit *C* is the efficient unit defining the technological frontier and *A* is an inefficient production unit. The available technology allows to produce Y_{FA} of the intended output using V_A amounts of input. The technical efficiency of *A* is then calculated as $E_A = Y_A/Y_{FA} < 1$, which is a measure of relative distance to the frontier. Technical efficiency in the case of production unit *C* is *EC=YC/YC=1.*

The technology producing pollution is a separate process, where the input *V* used in the intended production technology also generates the pollution output *Z*. In Figure 3.1B, the minimal amount of pollution is produced by unit *A*, which is the environmental efficient unit defining the technological frontier of the pollution-generating technology. Poor management might create inefficiencies in the production process that could yield more than this minimal level of undesirable outputs, which is the case of production unit *C*. In this case the environmental efficiency of C, the inefficient unit, is *EEC=ZFC/ZC<1*. Environmental efficiency of production unit *A* is *EEA=ZA/ZA=1*.

Pollution in Figure 3.1B cannot be disposed below the minimal level defined by the production frontier, which means that it is not possible to produce less than Z_F or ZA pollution with the available technology if a V_C or VA amounts of input are used, respectively. The only way to reduce pollution for an environmental efficient unit like *A* is to reduce the amount of input VA used, which will result in reduced production of the intended output.

Figure 3.1C shows the intersection of the two technologies in output space, assuming a fixed amount of inputs for units *A* and *C*. All production units are within the production possibility set that shows that: a) no unit can produce more of the desirable output than *C* (Y_C), and b) no unit can produce fewer polluting outputs than *A* (Z_A). The optimal point (highest production and minimum pollution) is represented by the corner point *F* in the figure. The by-product technology avoids the problem of assuming a uniform disposability of intended and polluting outputs and determines that a production unit cannot freely reduce the amount of pollution being generated as the result of the intended production process.

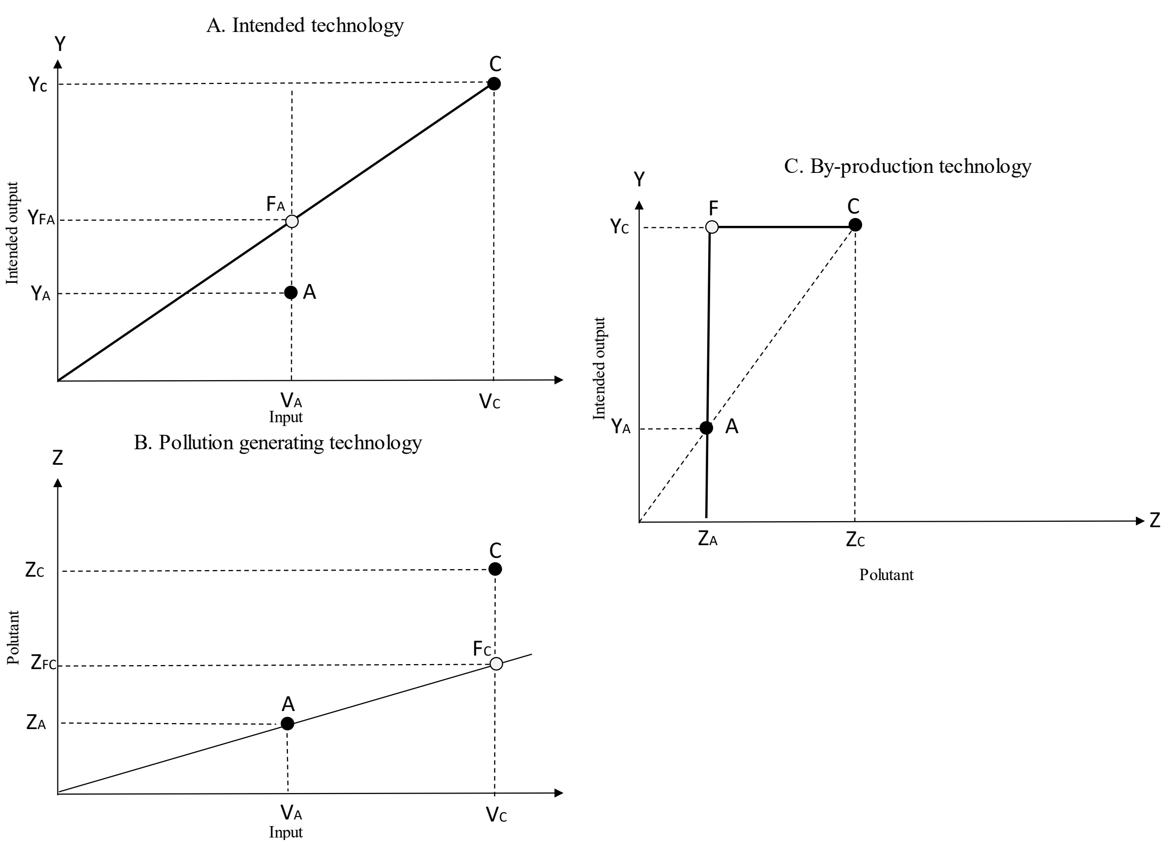
We can now incorporate environmental efficiency to the decomposition of TFP as shown in Appendix AI.

$$TFP = (TE \times EE)^{0.5} \times T \qquad (3.2)$$

where TE is technical efficiency, EE is environmental efficiency and T is technology or potential productivity. Percentage changes in TFP can be decomposed as:

$$dTFP/TFP = 0.5 \times [dTE/TE + dEE/EE] + dT/T \qquad (3.3)$$

Figure 3.1–A by-product production technology



Source: Adapted from Murty, Russell and Levkoff (2012, p.126)

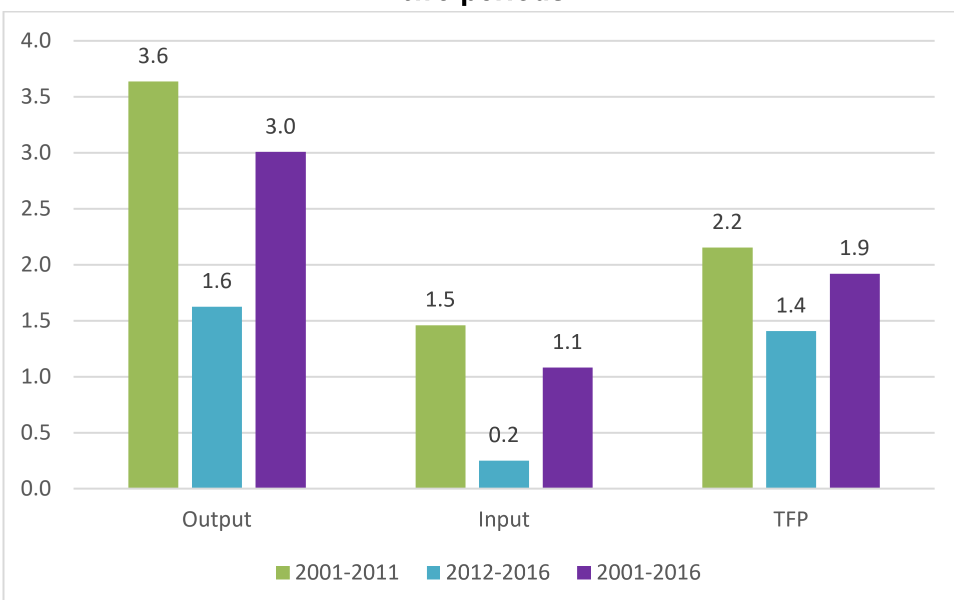
In sum, under the by-product technology, given fixed levels of some inputs and/or some intended outputs, there is always a minimal amount of pollution that cannot be reduced without incurring in extra costs (reduced production of the desired output). Given that this is a production process of a “bad”, we refer to the most efficient production unit as that producing the least pollution per unit of input.

Data used to calculate TFP and efficiency combine the latest available version of the ERS-USDA (2019) and GHG emissions from FAO (2020). Inputs used in crop production include cropland, machinery, and fertilizer while inputs used in livestock are pasture, animal stock and feed. Total labor in agriculture was allocated to crop and livestock production following a simple proportional method as described in Lips (2017). Crop and livestock output is from FAO measured in 2004-2006 international dollars. The dataset for efficiency analysis consists of 152 countries from different regions, including 24 countries from LAC. GHG emissions from FAO were calculated using Tier 1 methodology which employs default emission factors and other parameters provided by the IPCC using simplifying assumptions about some carbon pools. Details on data used can be found in Appendix II.

4. Performance of agriculture

Agricultural output growth shows two clearly differentiated periods between 2000 and 2016 (Figure 4.1). The average annual growth rate of output between 2001 and 2011 was 3.6 percent, decreasing to 1.6 percent in 2012-2016. During the period of fast growth, output growth was driven by TFP growth (2.1 percent) but with a significant contribution of growth in total inputs (1.5 percent). With the slowdown of production after 2011, TFP growth decreased to an annual average of 1.4 percent while growth in input decreased to almost zero (0.2 percent). TFP growth rates of 1.4 percent are not small when compared to historical trends, but the change signals the end of the favorable period for LAC's agriculture.

Figure 4.1–LAC's average annual growth rates of agricultural output, input and TFP for two periods

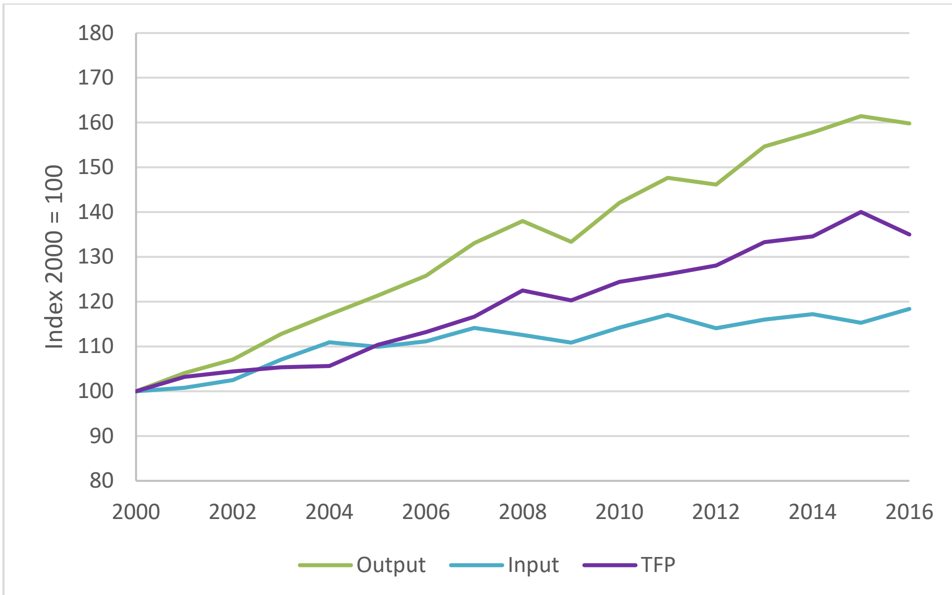


Source: Produced by authors based on USDA-ERS (2019) and FAO (2020).

Evolution of output, input and TFP during the analyzed period are shown in Figure 4.2. The figure clearly shows the stable growth between 2001 and 2011, the impact of the 2008 crisis and the end of the commodity price boom in 2011. It also shows fast input growth until 2004 when it reached a plateau with no significant changes after that year, except for increased growth in 2010-2011, probably associated to economic activity bouncing back after the economic crisis of 2008.

The observed patterns of TFP growth are similar to those of output as TFP has been the main driver of output growth during the period.

Figure 4.2–Indices of output, input and TFP for LAC's agriculture, 2000-2016



Source: Elaborated by authors based on USDA-ERS (2019) and FAO (2020).

Even though we have only four years to measure performance during the post-commodity price boom, growth rates of output in the last period are significantly smaller than those in the first period (Table 4.1). Comparing growth rates of 24 LAC countries in two periods we find that between 2000 and 2011, average annual agricultural output growth among these countries was 2.7 percent, compared to 1.5 percent on average between 2012 and 2016. This difference in growth rates between periods is statistically significant at the 5 percent level.

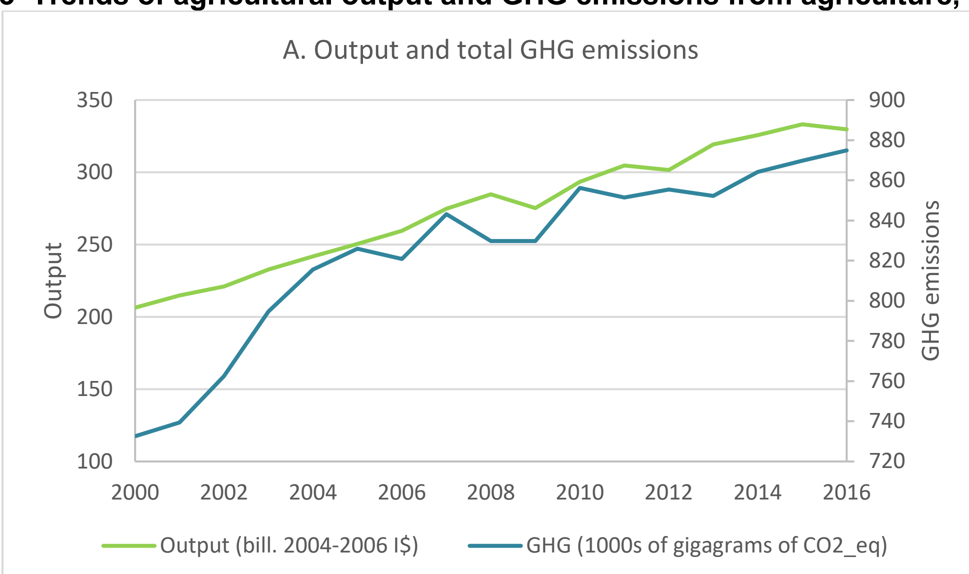
Table 4.1–Two-sample t test of output growth rates in 2003-2011 and 2012-2016

Group	Obs.	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
1	264	2.687	0.393	5.89	1.998	3.376
2	120	1.458	0.468	5.53	0.403	2.513
combined	384	2.302	0.294	5.75	1.726	2.880
diff		1.229	0.631		-0.126	2.470
diff = mean(1) - mean(2)						t=1.9471
Ho: diff = 0				degrees of freedom		382
Ha: diff < 0		Ha:	Ha: diff from 0			Ha: diff
Pr(T < t) = 0.9739		Pr(T >t) = 0.0520			Pr(T >t) =	0.0261

Source: Produced by authors based on FAO (2020).

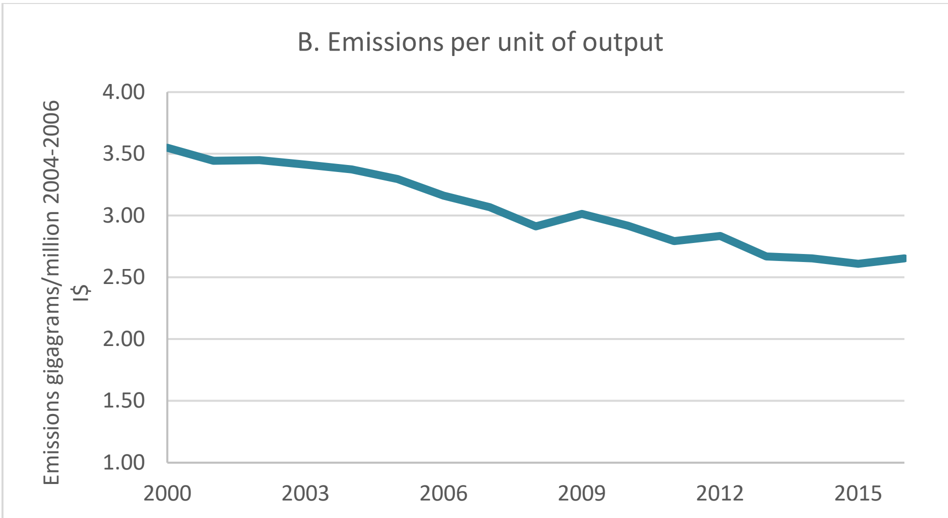
We also report trends of GHG emissions from agriculture measured in gigagrams of CO2_eq (Figure 4.3) and the evolution of GHG emissions per unit of output (Figure 4.4). Emissions increased with output growth as expected but output has grown faster than emissions, resulting in a reduction in emissions per unit of output. Figure 4.5 shows growth rates of output and emissions for the fast-growing period between 2000 and 2011 and for most recent years. Before 2011, output grew faster than emissions (3.5 percent compared to 1.4 percent, respectively). After 2011, growth in emissions fell to only 0.6 percent per year, compared to 1.4 percent annually between 2000 and 2011 and emissions per unit of output decreased faster during rapid growth (-2.1 percent) between 2000 and 2011 than in recent years (-1.0 percent).

Figure 4.3–Trends of agricultural output and GHG emissions from agriculture, 2003-2016



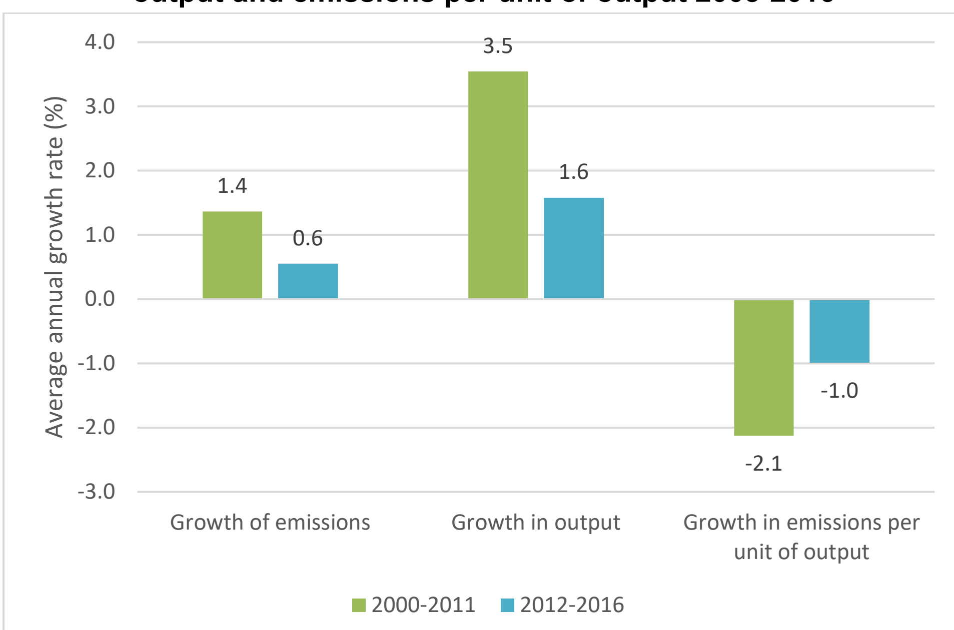
Source: Produced by authors based on FAO (2020)

Figure 4.4–GHG emissions per million of 2004-2006 dollars of agricultural output, 2003-2016



Source: Produced by authors based on FAO (2020)

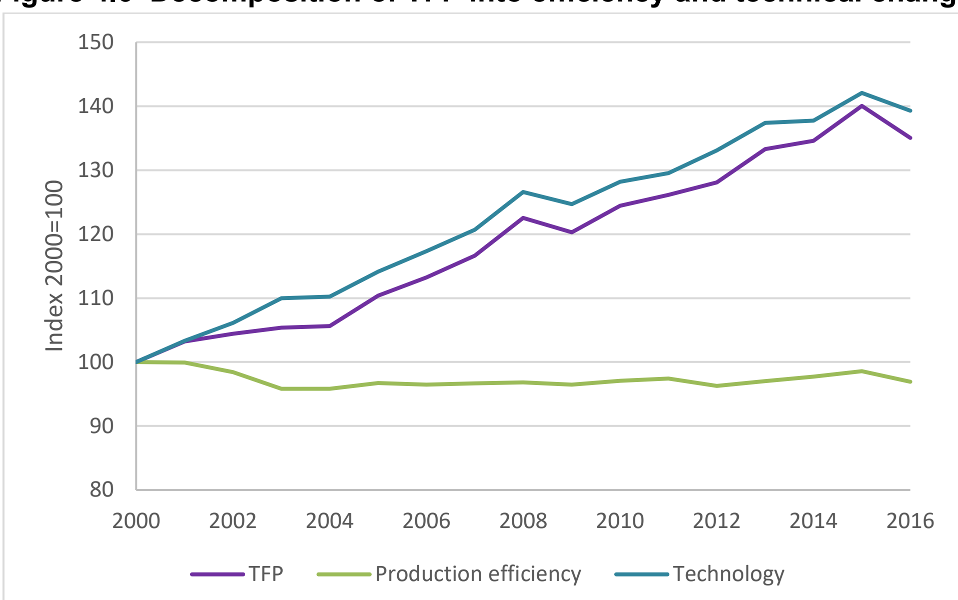
Figure 4.5–Average annual growth rates of GHG emissions from agriculture, agricultural output and emissions per unit of output 2003-2016



Source: Produced by authors based on FAO (2020)

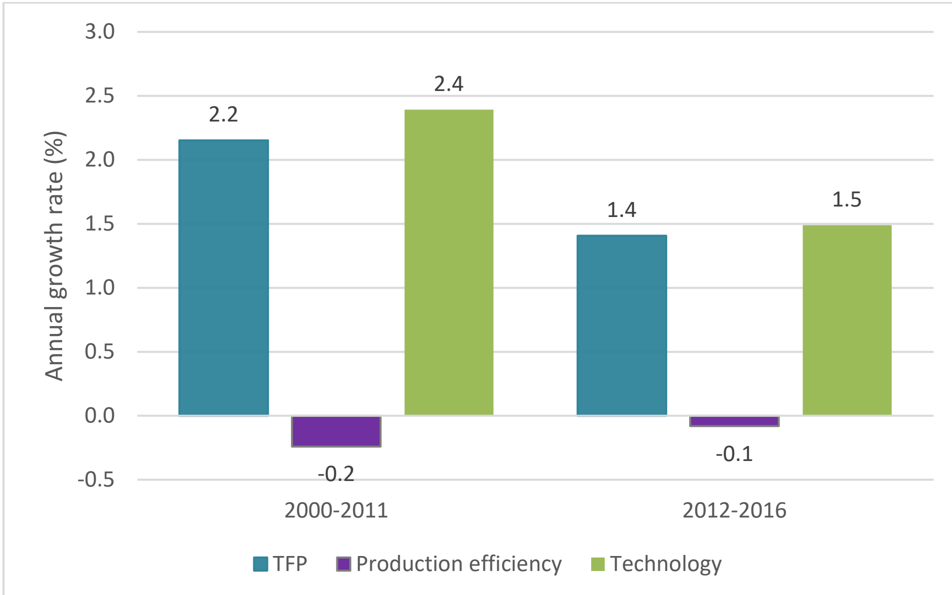
TFP growth in agriculture during the analyzed period was driven by technical change as shown in Figure 4.6. This means that new incorporated technologies allowed the region to increase potential output per unit of total input. On the other hand, not all countries were able to take advantage of new technologies in the same way, so fast movements of the frontier by more innovative countries leave behind countries that couldn't adopt new technologies at the same pace. Until 2011, production efficiency did not change significantly but shows a slight decreasing trend, as some countries fall behind the fastest growing countries. Figure 4.7 shows that the technological frontier (technology) shifted at an average rate of 2.4 percent during 2000-2011, almost the same as that of TFP growth (2.2), compensating for an annual growth in efficiency of -0.2 percent. After 2011, the annual rate of technical change decreased to 1.5 percent while growth in efficiency shows a slight decrease of -0.1 percent.

Figure 4.6–Decomposition of TFP into efficiency and technical change



Source: Produced by authors based on USDA-ERS (2019) and FAO (2020)

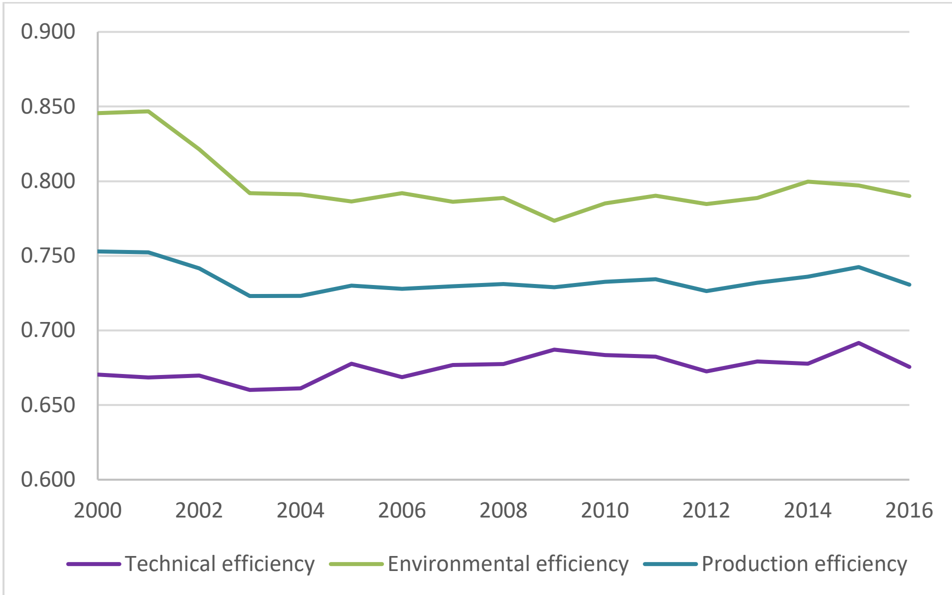
Figure 4.7–Growth decomposition of TFP into efficiency and technical change, annual average growth rates (percentage)



Source: Produced by authors based on USDA-ERS (2019) and FAO (2020)

The observed reduction in efficiency is mostly explained by a loss in environmental efficiency, while technical efficiency remains almost unchanged (Figure 4.8). However, these changes are very small, with a reduction of environmental efficiency of 6.5 percent between 2000 and 2011. With the slowdown in growth after 2011, environmental efficiency starts recovering but overall, the gains from increased environmental efficiency are very low.

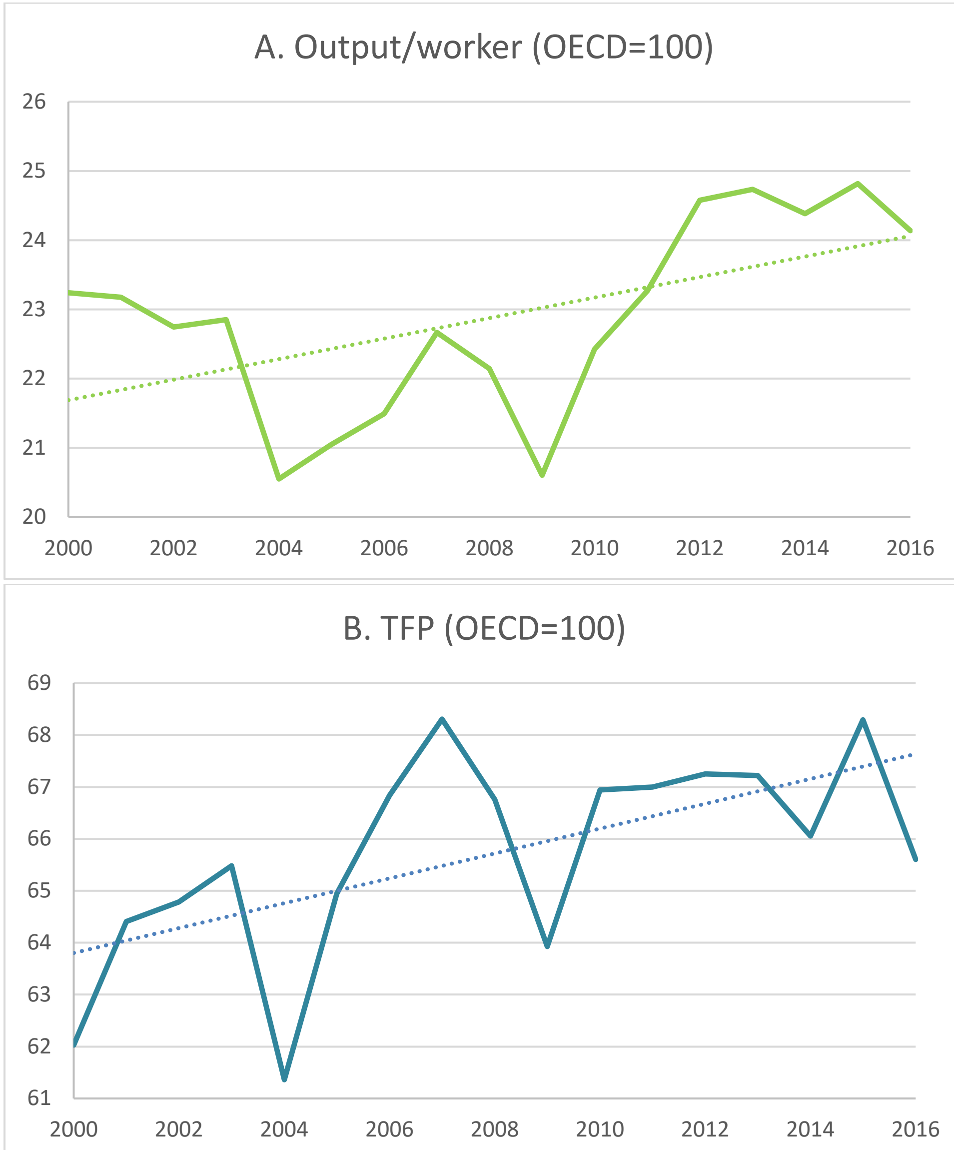
Figure 4.8–Decomposition of production efficiency into technical and environmental efficiency.



Source: Produced by authors based on USDA-ERS (2019) and FAO (2020).

We measured the performance of agriculture in the region relative to the performance of agriculture in OECD countries (Figure 4.9). The period of high commodity prices and fast agricultural growth in LAC resulted in a reduction of the labor productivity gap between the region and OECD countries, although this reduction was only of 2.5 percentage points (from 21.5 percent of OECD values in 2000 to 24 percent in 2016) if we compare the values on the trend line (Figure 4.9A). The TFP gap between LAC and OECD also decreased (Figure 4.9B). The trend line of LAC's relative TFP levels increased from 64 in 2000 to 68 in 2016.

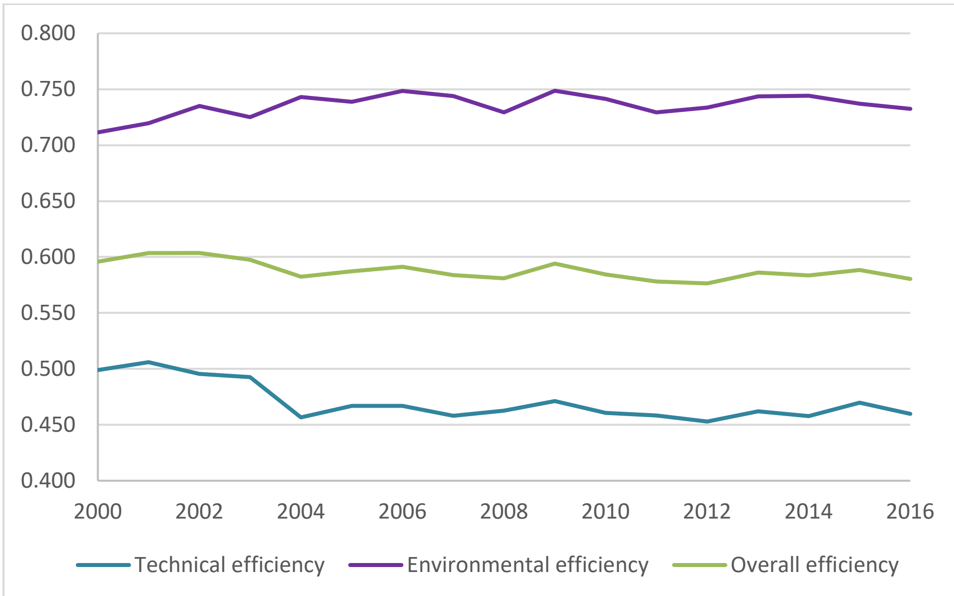
Figure 4.9–LAC's agricultural output per worker and TFP levels relative to OECD's



Source: Produced by authors based on USDA-ERS (2019).

The evolution of efficiency measured against the world frontier rather than the regional frontier is another measure of the relative performance of the region (Figure 4.10). The Figure shows that production in LAC was able to keep up with growth in the world's technological frontier, although technical efficiency is still low, at above 0.45. On the other hand, environmental efficiency increased between 2000 and 2004 but remained almost unchanged after that year, fluctuating around 0.73. Notice that technical and environmental efficiency measured at the regional frontier are higher and close to 0.68 and 0.78, respectively.[2] This means that the region could still accelerate TFP growth by reducing the technology gap with the world frontier.

Figure 4.10–LAC's technical and environmental efficiency measured relative to the world production frontier, 2000-2016.



Source: Produced by authors based on USDA-ERS (2019) and FAO (2020)

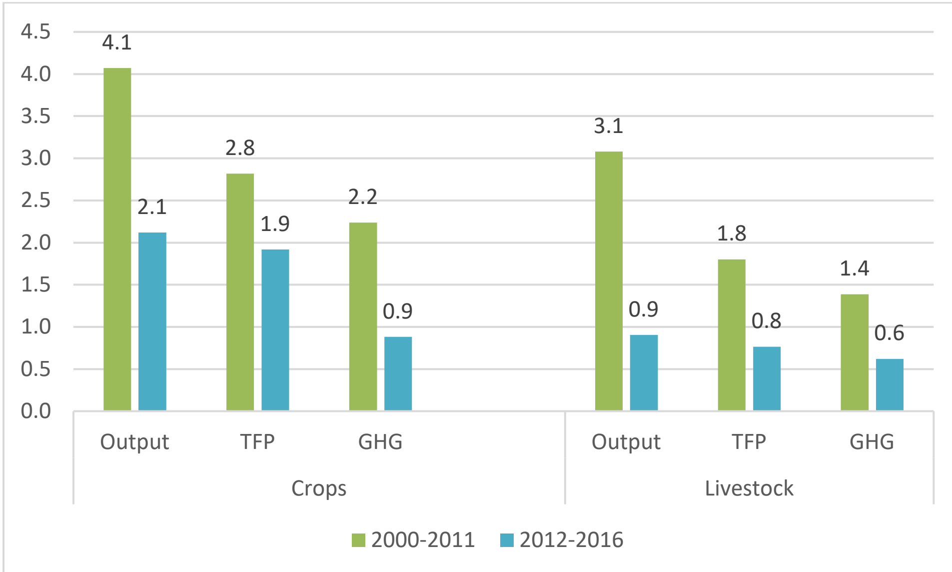
[2] Data not shown but available upon request.

5. Crop and livestock production

Average growth rates for output, TFP and GHG emissions for both crop and livestock production are shown in Figure 5.1. During the period of high commodity prices, crop and livestock production grew at an annual rate of 4.1 and 3.1 percent, respectively. TFP growth was also higher in crop production (2.8 percent compared to 1.8 percent in livestock production). GHG emissions also increased faster in the crop sub-sector (2.2 percent) than in livestock production (1.4 percent), although as will be shown below, emissions from livestock are much higher in absolute terms than emissions from crops. During the slower growth period after 2011, growth in crop production dropped to 2.1 percent annually (half the growth rate than in the previous period) while TFP growth dropped from 2.8 to 1.9 percent. In the case of livestock, growth in output during 2012-2016 slowed down to only one-third of growth in the previous period (from 3.1 percent to 0.9 percent) while average growth in TFP dropped to 0.8 percent.

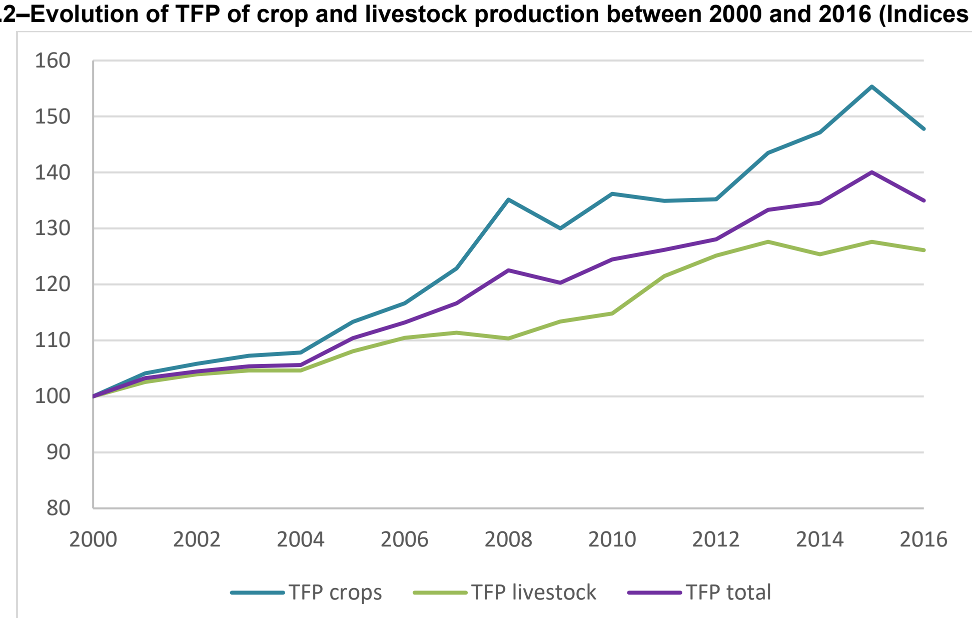
Growth in GHG emissions in both crop and livestock subsectors decreased after 2011 to almost half of growth observed in 2000-2011. Figure 5.2 shows trends in agricultural TFP decomposed into crop and livestock TFP. Crop production was the main driver of agricultural TFP growth until 2008. After that year and until 2012, livestock replaces crops as the fastest growing subsector, when there was almost no growth in crop production. After 2012, livestock TFP seems to reach a plateau and crops is again the subsector driving growth after during the last years of the period.

Figure 5.1–Growth rates of output, TFP and GHG emissions for crop and livestock production in LAC, 2003-2016.



Source: Produced by authors based on USDA-ERS (2019) and FAO (2020)

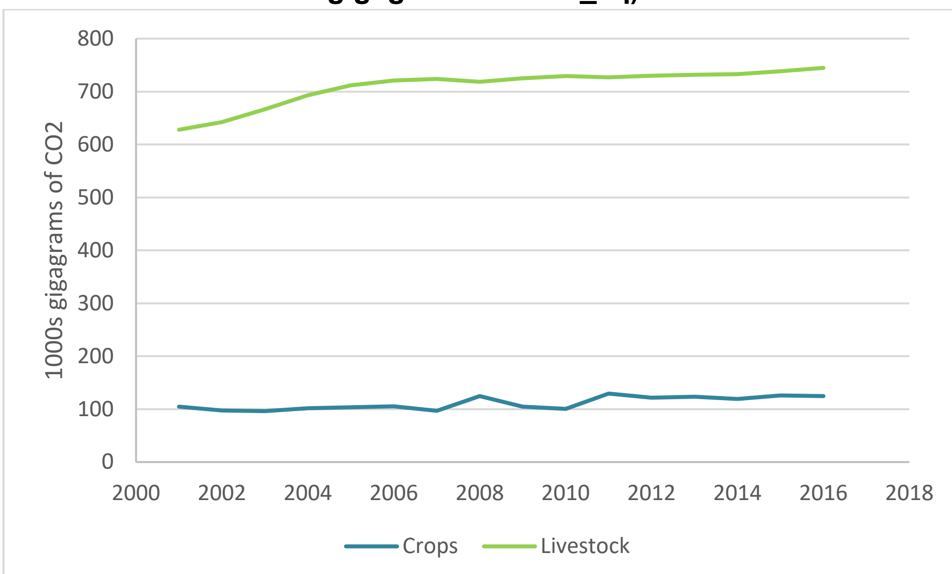
Figure 5.2–Evolution of TFP of crop and livestock production between 2000 and 2016 (Indices 2000=100)



Source: Produced by authors based on USDA-ERS (2019)

The livestock sector generated six times more GHG emissions than the crop sector in 2000, as shown in Figure 5.3. This difference between livestock and crop emissions increased after fast growth in livestock emissions in the early 2000s. Most of the emissions from agriculture in LAC come from enteric fermentation in ruminants and manure left in pastures. In crop production, the major sources of emissions are fertilizer, rice cultivation and crop residues, with more than half of total emissions from crops generated by fertilizer use.

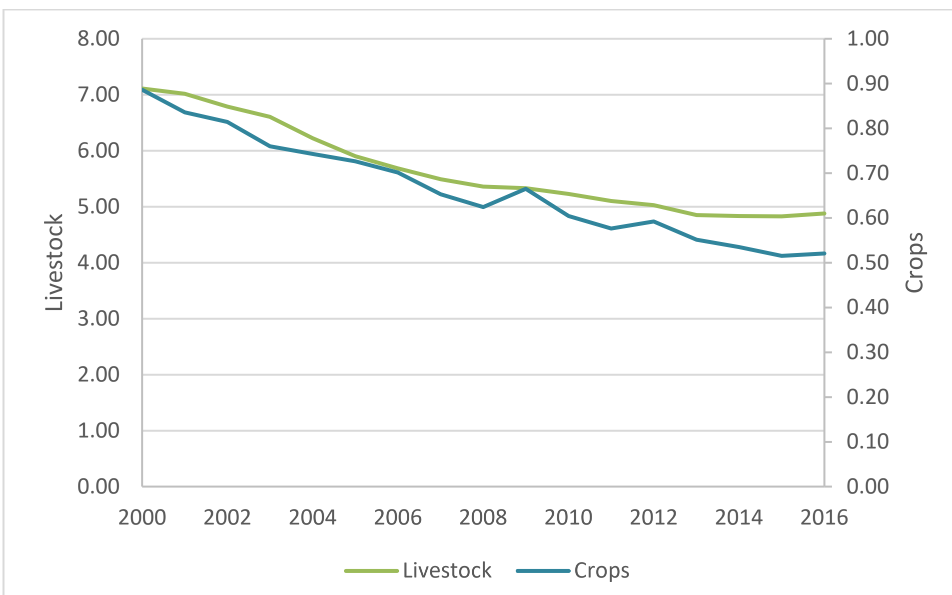
Figure 5.3–GHG emissions from crop and livestock production, 1992-2016 (1000s of gigagrams of CO2_eq)



Source: Produced by authors based on FAO (2020).

As in the case of the agricultural sector, emissions per unit of output are also decreasing in the crop and livestock subsectors (Figure 5.4). Emissions per unit of output from livestock decreased almost linearly after 2000 from 9 gigagrams per million dollar of output, stabilizing at a value of 6 gigagrams per million dollar after 2012. In the case of livestock, there are effective measures to reduce the emission of greenhouse gases per unit of animal product. A study by Nin-Pratt, Freiria and Munoz (2019) show that the livestock sector in Uruguay has seen a historical increase in productivity after 2002, driven by technical change as the result of an increase in the area under cultivated pasture and the use of grain and supplements associated to growth in dairy production and to more intensive fattening of cattle. Changes in nutrition increased productivity but also resulted in a significant reduction in emissions per unit of output. This was not only the result of the direct effect of improved quality of feed on existing animals, but most important, better nutrition changed the animal stock structure by reducing the slaughter age of steers and increasing the offtake rate of females as the result of a reduction of breeding age. The result was an increase in the number of productive animals in the stock, higher output per animal and an overall reduction of emissions per unit of output. A similar impact of improved nutrition occurred in Paraguay, where beef production more than doubled between 2005 and 2016, driven by technical change and a significant contribution of efficiency growth. The adoption of high-yielding tropical cultivated pastures, well adapted to growing conditions, together with improvements in genetics of the animal stock, were the main drivers of increased productivity. As in the case of Uruguay, emissions from enteric fermentation per unit of output were reduced by half as the result of improved nutrition through cultivated pastures but there is still a wide margin of improvement when compared to emissions in Uruguay (Nin-Pratt, Freiria and Munoz, 2019).

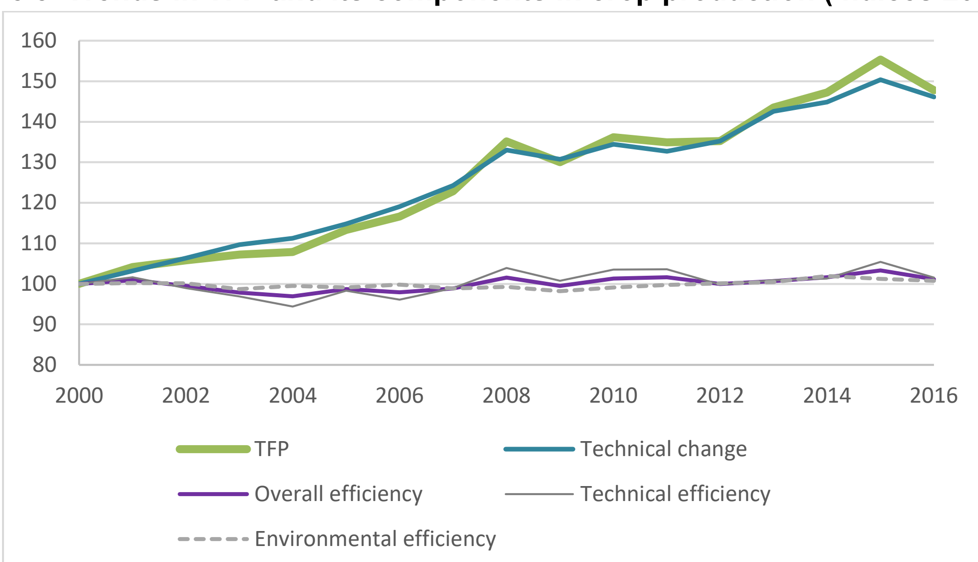
Figure 5.4–GHG emissions per unit of output, 2000-2016 (gigagrams/million 2004-2006 I$)



Source: Produced by authors based on FAO (2020)

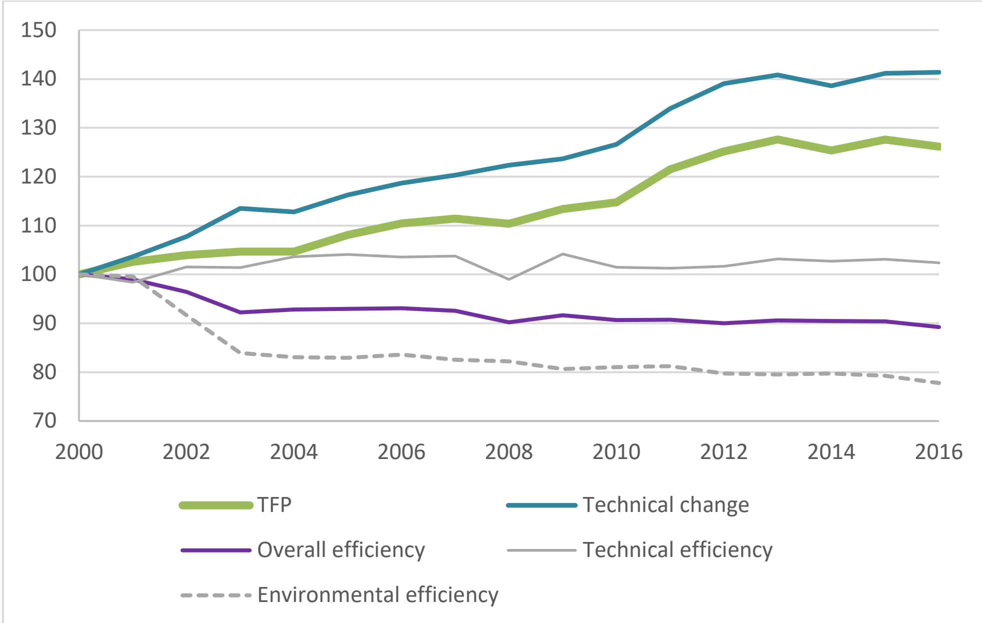
Figures 5.5 and 5.6 show the TFP decomposition into efficiency and technical change for crop and livestock production, respectively. In the case of crop production, potential output per unit of input, expressed as technical change, increased almost 60 percent between 2000 and 2016, clearly driving TFP growth. In the case of livestock, growth was also driven by technical change, while efficiency remained almost unchanged as the result of a slight increase of technical efficiency (5 percent in 16 years) and a reduction of environmental efficiency of a similar magnitude. Notice that efficiency decreased, particularly in livestock, in the 2000s. This is a common outcome during periods of fast growth as not all countries can grow at the same speed during the same period. As the technological frontier expands driven by fast technical change in the leading countries, other countries cannot keep the pace and fall behind the frontier, which results in increased inefficiency.

Figure 5.5–Trends in TFP and its components in crop production (Indices 2000=100)



Source: Produced by authors based on USDA-ERS (2019)

Figure 5.6–Trends in TFP and its components in livestock production (Indices 2000=100)



Source: Produced by authors based on USDA-ERS (2019)

Country performance[3] for the period 2000-2016 is shown in Table 5.1 while figures 5.7 and 5.8 show main activities driving growth in crop and livestock production, respectively. The period of fast growth between 2000 and 2011 was driven by Brazil with average annual growth rates in crop and livestock production of 5.2 and 4.0 percent, respectively (Table 5.1). Argentina shows a mixed picture, with high growth in crop production (4.1 percent) but low growth in livestock production (0.8 percent). Mexico, the other major economy in the region, shows a relatively poor growth performance in crop production until 2011 when compared with Brazil and Argentina (1.4 percent annual growth) but performed better in livestock production, with an average growth rate of 2.5 percent. The fastest growth in crop production, 6.1 percent, is observed in Bolivia, Paraguay and Uruguay (BPU), driven by the fast expansion of soybean production (Figure 5.7) and a strong performance of the livestock sector with an average growth rate of 3.0 percent. Central America also shows high growth during the period with 3.8 percent growth in crop production and 3.7 percent annual growth in livestock production. Growth in Andean countries is below that of Brazil,

[3] Performance of the agricultural sector at the country level can be found in Appendix III.

Central America and BPU between 2000 and 2011 but above 2.0 percent growth in crop production and 3.4 percent growth in livestock production before 2011.

During the period of fast agricultural growth, both yield and area expansion contributed significantly to growth in crop production. The highest growth in cultivated area occurred in BPU (6.7 percent annually) but also Argentina, Brazil and Central America increased harvested area. Annual growth in yields is in most cases lower than area expansion but still significant, going from 2.6 percent in Brazil to 1.0 percent in Central America. Most growth in yields is explained by fast growth in TFP, especially in BPU (4.5 percent), Central America (3.8 percent) and Brazil (3.4 percent). The fact that TFP growth is higher than growth in yields means that the region reduced input per hectare of harvested area, indicating incorporation of new technology which corresponds with results in Section 4 where it was shown that TFP growth was driven by technical change. In other words, during the commodity boom period, the region seems to have transformed agriculture into a more productive and competitive sector. The expansion of soybean production (Figure 5.7) incorporating new technologies, the dynamic role in livestock growth played by poultry and the expansion and intensification of beef production (Figure 5.8) might explain a significant part of this transformation in Brazil and UPB. But it was not only South America benefiting from this transformation. Central America have also had high and steady TFP growth during the period, driven by growth in cash crops, maize and fruits and vegetables and balanced growth across the livestock sector. Growth in the Andean countries and Mexico was slower than in other regions during 2000-2011 but they still show an average growth above 2 percent in output and TFP between 2000 and 2016.

The agricultural growth slowdown after 2011 affected the whole region with the only exception of crop production in Mexico which grew at an average rate of 5.5 percent between 2011 and 2016, compared to only 1.4 percent before 2011 (Table 5.1). But even this slowdown shows the extent of the agricultural transformation in the region during 2000-2011. First, the region has been able to sustain growth in crop production at relatively high rates compared to historical performance.

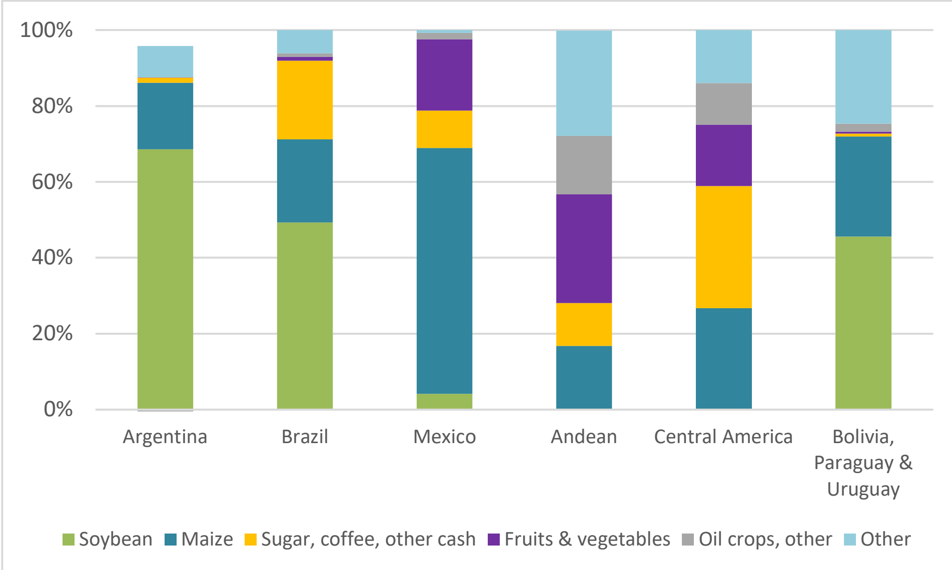
Central America, BPU and Argentina were still growing at average rates close to or above 3 percent per year despite the worsened economic environment. The worst performer in 2011-2016 is Brazil as the result of a dire macroeconomic situation in recent years. Second, the slowdown in crop production between 2011 and 2016 can be attributed to slower expansion of harvested area and slower TFP growth. However, TFP growth was still relatively high during this period when compared to growth rates in the 1980s and 1990s. Finally, results for the livestock sector presented in Table 5.1 show that growth between 2011 and 2016 is much lower than growth in crop production during the same period. Only Brazil shows growth rates above 1.0 percent which makes it the best performer in livestock production, also with the highest TFP growth (1.8 percent).

Table 5.1 Decomposition of output annual average growth rate in crop and livestock production, 2001-2011 and 2012-2016 (percentage)

	2001-2011					2012-2016				
Region	Output	Area	Yield	TFP	Cropping pattern[(a)]	Output	Area	Yield	TFP	Cropping pattern
Crops										
Argentina	4.1	2.8	1.4	1.7	-0.1	2.7	0.6	1.3	2.5	0.7
Brazil	5.2	2.6	2.6	3.4	-0.1	1.0	2.1	0.0	1.5	-1.0
Mexico	1.4	-1.1	1.3	0.8	1.2	5.5	2.7	2.6	2.7	0.3
Andean countries	2.3	0.5	1.6	1.8	0.2	2.1	0.5	0.3	1.3	1.3
Central America	3.8	2.0	1.0	3.8	0.8	3.1	0.9	1.1	1.1	1.2
Bolivia, Paraguay & Uruguay	6.1	6.7	1.1	4.5	-1.8	3.3	2.0	0.9	1.7	0.5
	Output	Stock	Yield	TFP	Stock composition[(b)]	Output	Stock	Yield	TFP	Stock composition
Livestock										
Argentina	0.8	-0.1	1.1	0.5	-0.3	0.9	3.9	-4.4	-1.3	1.4
Brazil	4.0	2.2	1.4	2.3	0.4	1.4	0.1	0.8	1.8	0.4
Mexico	2.5	0.9	1.2	1.1	0.4	0.2	1.7	-1.3	-0.3	-0.2
Andean countries	3.4	2.8	1.0	2.1	-0.3	0.7	-0.1	0.6	0.5	0.2
Central America	3.7	3.1	0.7	1.0	0.0	0.7	1.5	-0.4	0.0	-0.4
Bolivia, Paraguay & Uruguay	3.0	2.0	0.5	1.3	0.6	0.4	1.6	-0.9	-0.4	-0.4

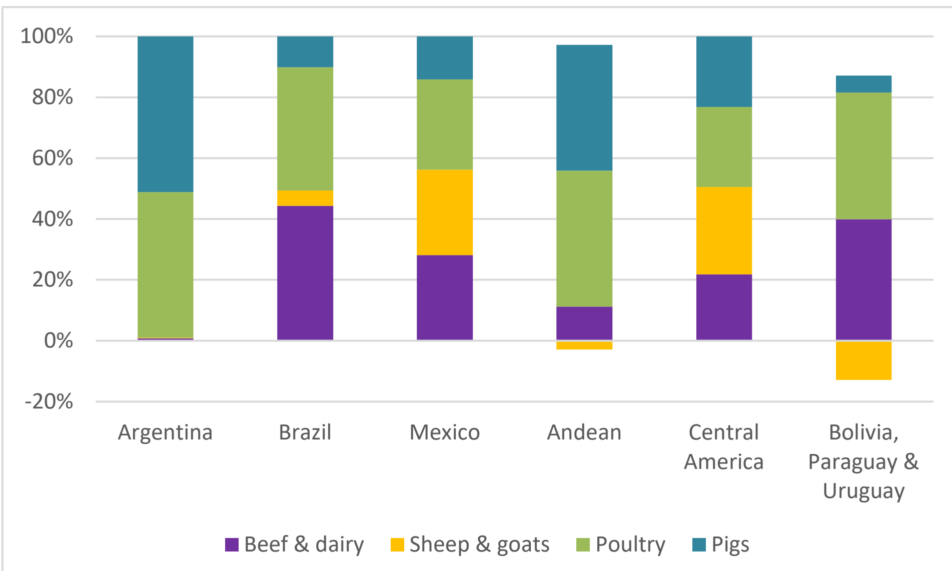
Source: Produced by authors based on FAO (2020)
Notes: Andean countries=Colombia, Ecuador, Peru and Chile; Central America=Guatemala, Honduras, Nicaragua, Costra Rica and Panama. (a) Changes in crop shares in total harvested área. (b) Refers to the animal stock structure in relative number of cattle, sheep and goats, pigs and poultry measured in cattle-equivalents.

Figure 5.7–Contribution of different activities to growth in crop production, 2000-2016 (percentage)



Source: Produced by authors based on FAO (2020).

Figure 5.8–Contribution of different activities to growth in livestock production, 2000-2016 (percentage)



Source: Produced by authors based on FAO (2020).

6. Summary and conclusions

Even though agriculture in LAC continues to grow after 2011, the observed growth slowdown marks the end of the favorable period for LAC's agriculture that started in 2003. Between 2000 and 2011, TFP growth in agriculture was driven by technical change, which means that new technologies allowed the region to increase the potential amount of output that can be produced per unit of input. Even though production shows high levels of efficiency at the regional level, when compared to the rest of the world, efficiency levels in the region are low and showed little improvement even during the commodity boom period. GHG increased with output growth as expected but output has grown faster than emissions, resulting in a reduction in emissions per unit of output with only a small reduction in environmental efficiency in the last 16 years.

The decomposition of agricultural growth into growth of crop and livestock production shows that during the commodity price boom, output and TFP in the crop and livestock sectors grew at a similar pace. In the case of crop production, potential output per unit of input, expressed as technical change, increased by 50 percent between 2000 and 2016, clearly driving TFP growth. GHG emissions on the other hand, increased much faster in crop than in livestock production but the livestock sector generates between six to eight times more GHG emissions than the crop sector as most emissions from agriculture are a by-product of beef and dairy production (enteric fermentation and manure). Although we observe a small reduction of the region's gap in agricultural output per worker with the OECD, rapid growth between 2000 and 2011 did not result in a reduction of the TFP gap between LAC and OECD countries.

Finally, results at the country/sub-regional level show that between 2000 and 2011 the fastest growth in agricultural production occurred in Brazil, Bolivia, Paraguay, Uruguay and Central America, driven by the boom of soybean production for export in the case of the South American countries and by cash crops, maize and fruits and vegetables in Central America. Most important, our results show that fast growth between 2000 and 2011 was not the result of business-as-usual fueled by high commodity prices. Instead, the region seems to have gone through a period of transformation with changes in the allocation of resources and the incorporation of new technologies that converted agriculture into a more productive and competitive sector. The expansion of soybean and maize production, cash crops, fruits and vegetables, the dynamic role in livestock growth played by poultry and the intensification of beef production are indicators of the scope of this transformation. Even under less favorable economic conditions after 2011 and slower growth, TFP growth rates in crop production have remained high in historical terms.

We conclude that the agricultural transformation of the past two decades have left the agricultural sector in LAC in a better position to cope with the more unfavorable macroeconomic environment and in the region and less dynamic global markets. It seems that the region will need to continue with policy reforms and strengthen political institutions to provide a better and more stable environment to sustain agricultural growth and consolidate the transformation of the past two decades.

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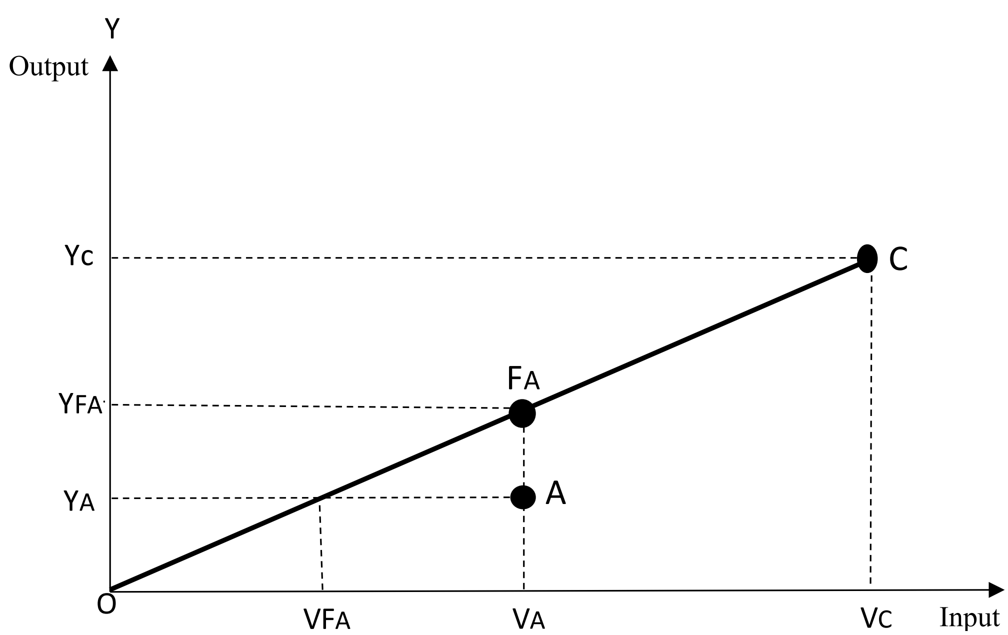
Appendix I: Methodology

We include here a graphical example using one output and one input, or equivalently, an index of aggregated output and an index of aggregated input so we can represent the production technology in two-dimensional space. Figure AI.1 represents input use and output of two production units: *A* and *C*. Unit *A* uses V_A input to produce Y_A output while C uses V_C input to produce Y_C output. Production unit *C* defines the technological frontier, represented in the figure by the line *OFAC*. No production unit can produce above the technological frontier, which means that for example, the maximum amount of output that can be produced using V_A quantity of input is *YFA*. The technology is represented by the area below the technological frontier in Figure AI.1 and consists of all feasible combinations of V and Y. The technological frontier can be thought also as the potential production that a production unit can produce with a certain amount of input. It is "potential" because production units using an amount of input V_A can also produce less output than the output at the frontier. This is the case of production unit *A* in Figure AI.1, producing output $Y_A<YF_A$. A production unit producing less than the potential output that can be produced with a certain amount of input is defined as inefficient. Using the example in Figure AI.1, we define a measure of efficiency for production unit *A* as follows:

$$EFF_A = Y_A/YF_A \qquad \text{(AI.1)}$$

where EFF_A and Y_A are production efficiency and output obtained by production unit *A* using input quantity V_A, and YF_A is maximum or potential output that can be obtained using V_A input given the available technology. Efficiency takes values between 0 and 1 as is the case of efficiency of unit A: $1>EFF_A>0$. On the other hand, production unit C in Figure AI.1 is at the frontier, which means it is an efficient unit with $EFF_C=YC/YF_C=1$, because $Y_C=YF_C$.

Figure AI.1–The production frontier and technical efficiency



Source: Elaborated by authors

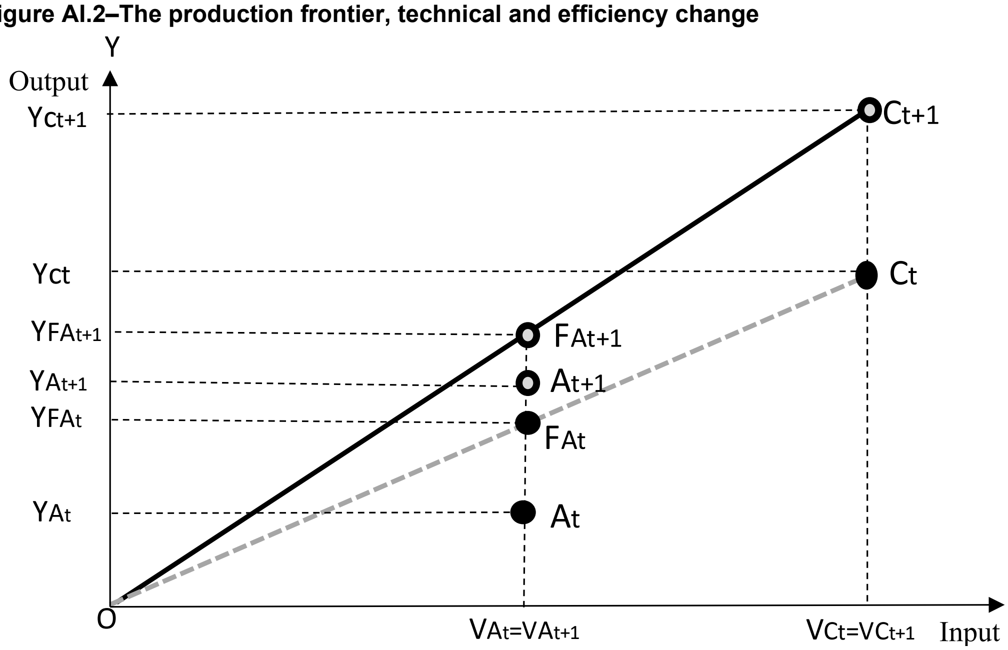
We can define efficiency from the output or the input side also looking at Figure AI.1. From the output side, efficiency of unit *A* is the maximum proportional increase in total output Y_A that can be achieved using amount of input V_A. This is efficiency as defined in equation (AI.1). From the input side, efficiency of unit A is defined as the maximum proportional reduction of total input V_A that allows the production of Y_A, that is, the same amount of output produced by A: $EFF_{Ai} = VF_A/V_A$. Using the definition of TFP in equation (3.1), we define TFP of unit *A* as $TFP_A=Y_A/V_A$. Now, replacing Y_A in the TFP equation by $Y_A=EFF_A \times YF_A$ from equation (AI.1) we obtain the decomposition of TFP into efficiency and potential productivity or technology:

$$TFP_A = EFF_A \times YF_A/V_A = E_A \times T \qquad \text{(AI.2)}$$

where *T* is potential productivity (TFP) or the ratio of potential output *YFA* and input *VA*.

Figure AI.2 represents the same production units (*A* and *C*) and production frontier (*OFAtCt*) as in Figure AI.1 but Figure AI.2 includes time (periods t and t+1) and changes in the levels of production of units *A* and *C* (from *YAt* to *YAt+1* and from *YCt* to *YCt+1*, respectively), but not changes in the use of inputs *(VAt=VAt+1)* and *(VCt=VCt+1)*. As unit C produces at the technological frontier (defines the frontier), increased output of unit C (with the same input) results in a shift of the technological frontier. This is equivalent to an increase in the potential output (through increased in TFP) that can produce with the same amount of input. Noticing that in our example, an increase in output is equivalent to an increase in TFP (there is no change in inputs), and without loss of generality we can explain TFP change for unit A as the product of efficiency change (change in the distance of A to the frontier) and technical change (a shift in the technological frontier.

Figure AI.2–The production frontier, technical and efficiency change



Source: Elaborated by authors

As shown in Figure AI.2, unit A increases output from Y_{At} to Y_{At+1} between periods t and t+1, a proportional increase of $dY_A=(Y_{At}+1/Y_{At})$. Starting from this expression, multiplying the right hand side by $(YF_{At+1}/YF_{At})\times(YF_{At}/YF_{At+1})=1$ and reorganizing terms we obtain:

$$dY_A = [(Y_{At}+1/YF_{At+1})/(Y_{At}/YF_{At})] \times(YF_{At+1}/YF_{\mathrm{At}}) = dEFF_A \times dT_A \qquad (AI.3)$$

The first expression in the RHS represents change in efficiency or dEFF (A's production in t+1 relative to output at the frontier in t+1 divided by A's production in t divided by production at the frontier in t). The second term represents technical change or the shift of the technological frontier between t and t+1 (dT). Values of dEFFA<1 mean that efficiency of unit A is decreasing: the frontier is shifting faster than productivity growth in *A*, and *A* is falling behind the technological frontier. Conversely, if dEFFA>1, production unit A is catching-up to the frontier.

Under the proposed approach, the overall efficiency, which we will call production efficiency (EFF), results from the average of technical (TE) and environmental efficiency (EE), where a low environmental efficiency "penalizes" the measure of productivity: the highest efficiency results from PUs that produce the highest amount of desired output per unit of total input while generating the minimum level of GHG emissions per unit of polluting inputs, given the available technology. Notice, however, that pollution is an externality for producers, that is, a consequence of livestock production that affects other parties without this being reflected in the private cost of production.

Data on shadow prices of inputs outputs are used to calculate the TFP indices. The frontier and associated measures of efficiency were calculated using DEA. For example, the LP problem for measuring technical efficiency is:

$$\begin{aligned} &\mathrm{TEo} \underset{\lambda,\theta}{=} \min \theta \\ &\textstyle\sum_{k=1}^{K} \lambda^k y^k \geq y^o \\ &\textstyle\sum_{k=1}^{K} \lambda^k x_n^k \leq x_n^o \theta \qquad \text{n = \{inputs\} and k= PUs} \end{aligned} \qquad (AI.4)$$

Technical efficiency of PU "o" (θ) is the minimum proportional contraction of inputs x^o used by this PU given output y^o subject to constraints that define the technology. The environmental efficiency as developed by Murty, Russell and Levkoff (2012), is obtained by solving the following optimization problem:

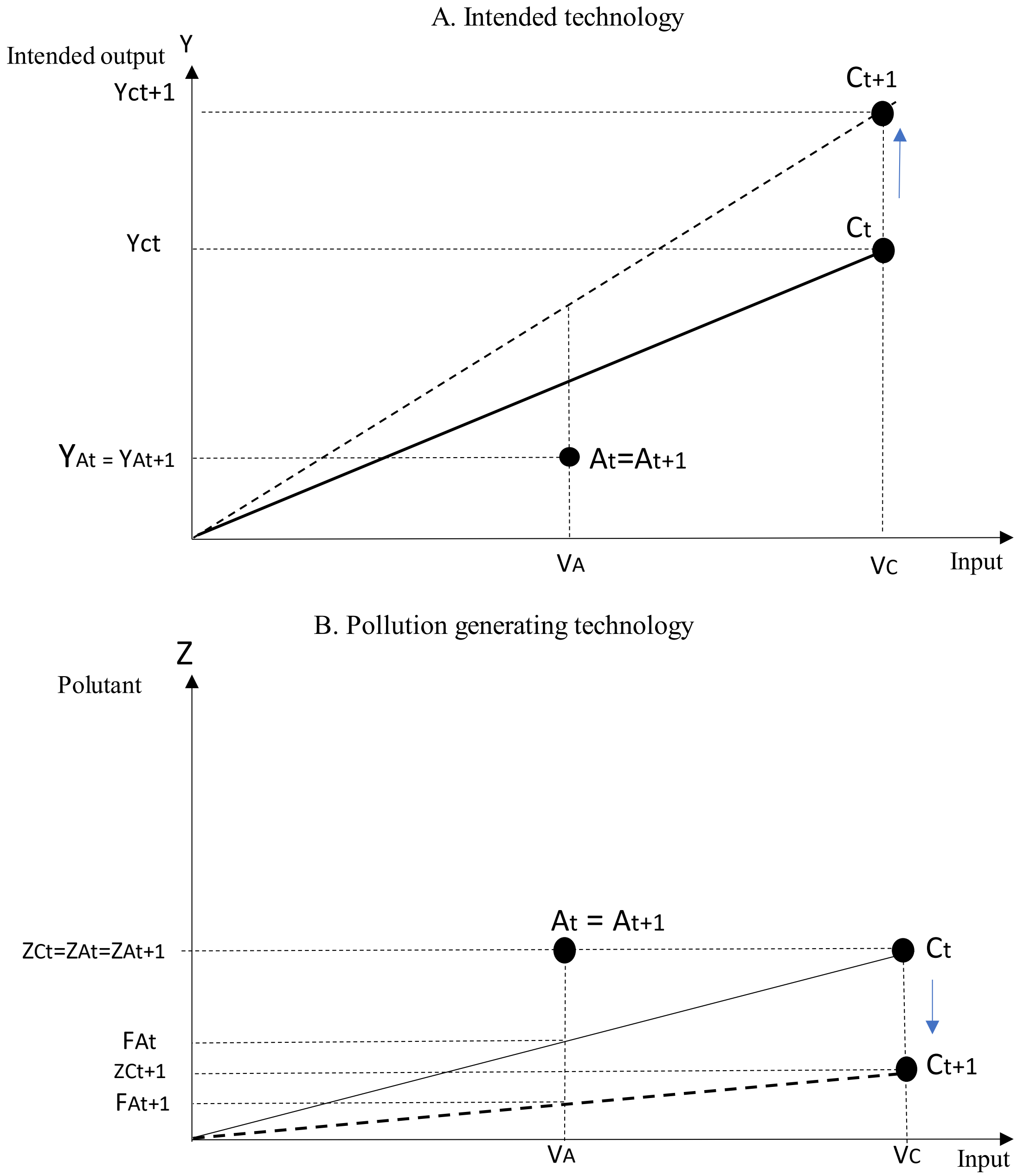
$$\begin{aligned} &\mathrm{EE} \underset{\mu,\gamma}{=} \min \gamma \\ &\textstyle\sum_{k=1}^{K} \mu^k Z_r^k \leq Z_{ro}\gamma \qquad \text{r =\{pollutants\}} \\ &\textstyle\sum_{k=1}^{K} \mu^k x_s^k \leq x_{so} \qquad \textit{k = PUs, and s = \{polluting inputs\}} \end{aligned} \qquad (AI.5)$$

LP (AI.5) calculates the minimum amount of pollution that can be produced given the amount and combination of polluting inputs used by PU "o". The overall efficiency is calculated as the average of the technical (ET=γ) and environmental (EE=θ) efficiency:

$$EFF = \frac{1}{2}(\theta + \gamma) \qquad (AI.6)$$

Notice the difference between environmental efficiency as defined above and the measure of emissions-intensity frequently used to measure intensity of emissions, calculated as total emissions per unit of output. Both output and pollution are the result of different production processes where some of the inputs used to produce the desired output are the inputs used in the production process of pollution. In this context it is possible, for example, to have growth that results in fewer emissions per unit of output and simultaneously have an increase in environmental inefficiency. A simple example of this case is shown in Figure AI.3. Unlike Figure AI.2, the technological frontier in the production of the desired output and in the production of pollution in Figure AI.3 is defined by the same production unit, C. The figure shows a shift in the technological frontier between periods *t* and *t+1* as C adopts new technology and produces in *t+1* more output and less pollution with the same amount of input than in *t*. Production unit A does not adopt the new technology during the period so it still produces the same amount of output in *t* and in *t+1*, with the same input. The consequences of these changes are the following. First, total output in *t+1* obtained by adding up output of A and C, is higher than total output in *t* given that *A* produces the same amount of output as in *t* but *C* now produces $Yct+1>Yct$. Second, total pollution from A and C in *t+1* is smaller than in *t* because *A* produces the same pollution in t and in t+1 but C produces less pollution: $ZCt+1<ZC$. Overall, the pollution-intensity ratio in t+1 compared to t becomes $(ZAt+ZCt+1)/(YAt+YCt+1)> (ZAt+ZCt)/(YAt+YCt)$. On the other hand, environmental efficiency decreases as the result of *A* falling behind the technological frontier as it does not adopt the new technology. Environmental efficiency for C is $EEC=1$ in t and in t+1 as this is the production unit defining the frontier. But in the case of *A*, environmental efficiency in *t+1,* decreases with respect to *t:* $EEAt+1=(FAt+1/ZAt) < EEAt=(FAt/ZAt)$. If *A* had adopted the technology and moved down to the pollution production frontier in *t+1*, then we would have had the case of reduced emissions per unit of output and increased environmental efficiency.

Figure AI.3–The case of technical change with in a by-product production technology with reduction in emissions per unit of output and increase in environmental inefficiency



Source: Elaborated by authors

Appendix II: Data

The input values are from the latest version of the ERS-USDA dataset from October 2019 (see Fuglie 2012, 2015) and include:

- Cropland: arable land plus land in permanent crops
- Irrigated area: Area equipped for irrigation (from FAO)
- Pasture: Area in permanent pasture (from FAO)
- Animal stock: obtained from FAO (2020) and includes cattle, sheep, goats, pigs and chicken, measured in "cattle equivalents" based on relative size and feeding requirements. Weights for each species are from Y. Hayami and V.W. Ruttan, Agricultural Development: An International Perspective (1985, p. 450), where dairy cattle are given a representative weight of 1.000. Species and their respective weights included are, dairy cattle (1.000), other cattle (0.800), goats and sheep (0.100), pigs (0.200), and poultry (10.0 per 1000 head).
- Machinery: total stock of farm machinery in "40-CV tractor equivalents" (CV=metric horsepower), aggregating the number of 2-wheel tractors, 4-wheel tractors, and combine-harvesters and threshers.
- Fertilizer: metric tons of N, P2O5, K2O fertilizer consumption. Data on N, P2O5, and K2O fertilizer consumption are from the International Fertilizer Association (IFA) where available, and otherwise from FAO (FAO data are used mainly for small countries).
- Feed: total metabolizable energy (ME) in animal feed from all sources, in 1000 megacalories (Mcal). Quantities of feed by source are from commodity balance sheets. Mcal per kg of feed for each type of feed are from "United States-Canadian Tables of Feed Composition: Nutritional Data for United States and Canadian Feeds, Third Edition," National Research Council, National Academies Press, 1982.
- Agricultural Labor: number of economically active adults in agriculture, as previously reported by FAO. Agricultural labor was allocated to crop and livestock production following a simple proportional method as described in Lips (2017). The reference data on labor use was obtained from USDA who publishes yearly data on the proportion of workers in field crops, specialty crops and livestock.

Output is also obtained from FAO and includes crop production and livestock production as the sum of the value of:

- Cow milk, whole, fresh
- Sheep meat and milk whole, fresh
- Goat meat and milk, whole, fresh
- Pig meat
- Chicken meat
- Hen eggs
- Wool, greasy

Output is measured in 2004-2006 international dollars. The dataset for efficiency analysis includes 152 countries from different regions, including 24 countries from LAC. To calculate productivity of the crop and livestock subsectors, total labor in agriculture was allocated by using a maximum entropy optimization method.

GHG emissions were obtained from FAO (2020) and were calculated following the 2006

Intergovernmental Panel on Climate Change (IPCC) Guidelines for National Greenhouse Gas Inventories based on collected data on livestock categories and feed. The IPCC has classified the methodological approaches in three different Tiers, according to the quantity of information required, and the degree of analytical complexity (IPCC 2006). The data from FAO uses Tier 1 methodology which employs default emission factors and other parameters provided by the IPCC using simplifying assumptions about some carbon pools. Total emissions from crops include: emissions from burning crop residues; burning savanna; crop residues; cultivated organic soils; rice cultivation; and from use of synthetic fertilizer. Livestock emissions include the following: enteric fermentation; manure applied to soils; manure left on pasture; and manure management.

Appendix III: results by country

Table AII.1– Growth rates of output and input per worker and TFP decomposition for agriculture, crops and livestock by country, 2001-2011 (percentage)

	Agriculture				Crops						Livestock					
Country	Output	Input	TFP	Efficiency	Output	Input	TFP	Eff.	Tech. eff.	Env. Eff.	Output	Input	TFP	Eff.	Tech. eff.	Env. eff.
Paraguay	5.9	1.7	4.5	0.4	7.4	1.8	5.5	1.4	4.0	0.8	2.9	1.5	1.4	-0.5	-1.1	0.0
Guatemala	4.9	1.0	3.9	-0.4	5.0	0.3	4.7	-0.3	2.0	-1.6	4.3	3.6	0.7	-0.7	1.6	-2.9
Brazil	4.7	1.6	3.0	0.0	5.2	1.7	3.4	0.3	0.5	0.0	4.0	1.6	2.3	-0.9	1.0	-2.8
Honduras	4.4	0.9	3.6	-0.3	5.1	-0.7	5.9	2.0	4.2	2.2	2.8	3.7	-0.8	-2.4	-3.2	-1.7
Peru	4.0	1.6	2.4	0.8	3.4	1.3	2.1	1.1	2.3	0.0	5.1	2.1	2.9	0.2	0.5	0.0
Nicaragua	3.8	2.1	1.8	-0.3	3.0	1.5	1.4	-1.0	-2.0	0.0	4.9	2.7	2.1	-0.6	0.7	-2.0
Dominican Republic	3.7	1.3	2.4	-0.9	4.0	0.6	3.3	-1.2	3.2	-5.3	3.2	2.2	1.0	-1.2	-0.6	-1.8
Haiti	3.6	0.5	3.2	0.6	4.2	0.6	3.6	1.6	3.2	0.0	1.2	0.2	0.9	-1.5	-0.3	-2.6
Bolivia	3.5	1.2	2.4	1.2	3.0	0.2	2.8	2.4	-0.7	5.4	4.3	2.4	1.9	-0.4	1.5	-2.2
Ecuador	3.4	1.5	1.8	0.0	3.1	1.4	1.7	0.9	2.4	-2.5	3.8	1.7	2.1	-1.2	0.8	-3.2
Uruguay	3.4	1.8	2.5	-1.1	7.8	3.0	4.6	0.1	1.6	0.2	1.4	0.9	0.5	-0.1	0.0	-0.3
Suriname	3.3	0.3	3.0	-1.6	3.2	0.3	2.9	-7.0	1.9	-13.3	3.7	0.2	3.5	0.0	0.0	0.0
Argentina	2.9	1.8	1.4	-1.1	4.1	2.4	1.7	-0.6	-1.1	0.0	0.8	0.3	0.5	-2.3	-1.9	-2.7
Chile	2.8	-0.4	3.2	-0.6	2.8	-0.8	3.6	-0.5	0.0	-0.7	2.8	0.2	2.5	-0.9	0.0	-1.9
Costa Rica	2.4	-0.3	2.7	-0.3	2.4	-0.5	2.9	0.0	0.0	0.0	2.6	0.3	2.3	-1.2	0.0	-2.5
Venezuela	2.2	1.2	1.1	0.1	1.0	1.3	-0.3	1.2	-1.3	4.2	3.0	1.2	1.8	-0.7	-0.1	-1.3
Mexico	1.9	1.0	0.9	0.1	1.4	0.6	0.8	0.2	0.3	0.0	2.5	1.4	1.1	0.0	0.0	0.0
Guyana	1.6	-0.1	2.0	-3.8	1.1	-0.6	1.6	-8.0	-0.9	-13.8	5.3	1.8	3.4	-0.3	-0.6	0.0
Colombia	1.5	0.7	0.9	-0.9	0.8	0.2	0.6	-0.1	-0.1	-0.2	2.3	1.1	1.1	-1.6	-0.4	-2.9
Panama	1.3	1.0	0.6	-1.0	-0.6	-0.2	-0.4	-1.2	-2.5	0.0	2.9	1.8	1.1	-1.2	0.0	-2.4
El Salvador	0.8	0.7	0.1	-2.4	0.3	0.6	-0.3	-6.1	-0.7	-8.9	1.5	0.9	0.6	-0.1	-0.1	0.0
Jamaica	0.5	-1.6	2.2	1.0	0.4	-2.0	2.4	1.5	0.0	2.8	0.7	-1.1	1.8	0.4	0.0	0.9
Belize	-0.3	0.4	-0.3	-4.2	-1.0	-0.6	-0.5	-4.6	-1.4	-5.5	3.8	3.8	0.0	-1.9	-0.2	-3.7
Trinidad and Tobago	-0.4	0.4	1.8	-0.6	-6.9	-2.6	-4.4	-3.5	-6.9	0.0	4.1	1.3	2.8	0.0	0.0	0.0

Source: Elaborated by authors

Table AIII.2– Growth rates of output and input per worker and TFP decomposition for agriculture, crops and livestock by country, 2012-2016 (percentage)

	Agriculture				Crops						Livestock					
Country	Output	Input	TFP	Eff.	Output	Input	TFP	Eff.	Tech. eff.	Env. Eff.	Output	Input	TFP	Eff.	Tech. eff.	Env. Eff.
Guatemala	4.2	-0.1	4.4	2.1	4.7	0.8	3.9	2.0	0.0	4.1	1.7	-2.7	4.5	1.1	3.6	-1.4
Bolivia	3.7	0.4	3.2	-0.2	5.5	0.5	5.0	1.6	5.1	-1.7	1.1	0.9	0.2	-0.4	0.5	-1.3
Mexico	3.1	1.6	1.4	0.2	5.5	2.8	2.7	1.3	2.6	0.0	0.2	0.5	-0.3	-0.4	-0.9	0.0
Dominican Republic	2.8	-0.9	4.4	0.8	4.9	-0.8	5.7	5.0	3.1	6.9	-0.7	-0.6	-0.1	-1.1	-1.0	-1.2
Guyana	2.5	-0.1	2.7	2.2	2.3	-0.8	3.1	1.7	4.7	-1.2	3.2	2.5	0.7	0.0	0.0	0.0
Paraguay	2.5	-0.3	3.2	0.5	3.1	-0.7	3.8	1.0	1.3	0.8	0.6	0.8	-0.2	0.2	1.4	-0.9
Peru	2.4	0.3	2.1	0.6	2.6	-0.3	3.0	0.7	1.4	0.0	2.1	1.2	0.8	0.4	0.7	0.0
Colombia	2.3	0.4	1.7	0.4	3.5	1.2	2.3	1.0	0.8	1.1	1.0	-0.2	1.2	-0.5	0.6	-1.5
Argentina	2.1	0.9	1.5	0.1	2.7	0.2	2.5	0.7	1.3	0.0	0.9	2.3	-1.4	-1.4	-1.2	-1.6
Haiti	2.1	0.4	2.0	0.9	2.6	0.2	2.4	1.4	2.8	0.0	-0.3	1.0	-1.2	-0.4	-0.6	-0.2
Costa Rica	2.0	2.5	-0.5	0.0	2.4	2.6	-0.2	0.0	0.0	0.0	0.9	2.4	-1.5	-0.6	0.0	-1.2
Suriname	1.7	-0.3	2.0	-1.3	2.4	0.0	2.4	-0.6	0.0	-1.2	-1.3	-2.0	0.7	0.0	0.0	0.0
Belize	1.6	1.5	0.7	-1.5	1.1	-0.6	1.7	-2.3	0.7	-5.1	3.9	5.3	-1.4	0.5	2.4	-1.2
Honduras	1.4	0.3	1.2	0.5	1.7	-0.5	2.2	1.2	1.7	0.7	0.6	1.8	-1.1	-0.5	-0.9	-0.2
El Salvador	1.3	-0.1	1.4	-0.3	1.4	0.7	0.6	-0.7	-2.2	0.7	1.2	-1.2	2.4	0.1	0.3	0.0
Brazil	1.2	-0.4	1.6	-0.5	1.0	-0.5	1.5	-1.1	-2.3	0.0	1.4	-0.3	1.7	-0.2	0.8	-1.1
Nicaragua	0.8	3.5	-2.8	-0.7	2.4	4.4	-2.0	-0.5	-1.1	0.0	-1.0	2.7	-3.6	-0.7	0.0	-1.4
Jamaica	0.6	-0.7	1.4	0.0	0.4	-0.9	1.3	0.0	0.0	0.0	0.9	-0.6	1.5	0.0	0.0	0.0
Trinidad and Tobago	0.4	1.3	-0.7	-0.1	0.0	0.7	-0.8	-1.6	-3.1	0.0	0.6	1.4	-0.8	0.0	0.0	0.0
Panama	0.4	0.2	0.5	1.3	-0.4	-1.0	0.6	2.9	5.9	0.0	1.0	0.7	0.3	0.6	0.0	1.2
Chile	0.3	0.1	0.3	-1.2	0.8	-0.3	1.2	-1.3	0.0	-2.5	-0.4	0.7	-1.1	-1.0	-1.0	-1.0
Uruguay	-0.3	0.8	-1.1	0.8	-0.4	1.0	-1.4	2.7	-5.3	11.3	-0.3	0.6	-0.9	0.2	0.0	0.3
Ecuador	-1.2	1.0	-2.1	1.1	-1.2	2.3	-3.4	1.0	-3.1	5.3	-1.0	-1.3	0.3	1.3	2.9	-0.2
Venezuela	-2.5	1.2	-2.8	-0.5	-6.2	-0.3	-5.9	-1.9	-8.0	4.6	-0.6	1.8	-2.4	-1.1	-1.3	-1.0

Source: Elaborated by authors