Output volatility and efficiency gains: evidence from Latin American gross value added

Kurt A. Hafner*

University of Heilbronn, Faculty of International Business Heilbronn, Germany

ABSTRACT
Based on gross value added (GVA) shares of economic activities from 1990 to 2014, the paper shows that convex growth-instability frontiers exist for 19 Latin American countries. Numerical simulations show that in 2011, Latin America's industry portfolios were below Markowitz's efficiency frontier, and that rearranging the shares of economic activities contributes to efficiency gains that are negatively linked to industrial diversification. Reducing output volatility, MERCOSUR countries with a low degree of industrial diversification would average relatively high efficiency gains, while the reverse is true for CACAM and CAN countries. Analyzing more recent industry portfolios, Latin American countries closed the efficiency frontier gap and captured efficiency gains in terms of lower output volatility and higher GVA growth rates. Convex growth-instability frontiers are confirmed by stochastic frontier analysis, which identifies variations in employment ratios and industrial diversification as the key sources of inefficiency.

1. Introduction

During the course of economic development, industrial diversification is believed to make countries and regions more stable by reducing their output volatility (Imbs and Wacziarg (2003), Koren and Tenreyro (2013)). Countries are becoming more efficient and industry portfolios should become more alike. However, it is not clear if this comes at the cost of lower economic growth rates as growth rates are high and volatile during a country’s economic catching-up phase, while countries in advanced stages tend to agglomerate with relative stable growth rates. Volatility of economic growth rates for catching-up economies in general, and for each of Latin American countries in particular, has grown in recent years – precisely in the low growth episode of 1970–2004 (Sahay and Goyal (2006)). As Latin American countries are lined up at different stages of economic development, their industry portfolios and income-stabilization potential vary widely, although the risk-return characteristics of some sectors might be more favorable than others for reducing output volatility and becoming more efficient.

Based on the approach and methodology of Hafner (2019,2020), we use the risk-return...
characteristics of regional economic activities to define and analyze Latin Americas’ industry portfolios. The idea is to apply modern portfolio theory (MPT) and stochastic frontier analysis (SFA) to GVA growth rates in 19 Latin America countries and to present evidence of regional convex growth-instability frontiers. MPT developed by Markowitz (1952) holds that efficient portfolios are usually created by strategic selection of different types of assets. Markowitz identified a parabolic efficient frontier, in which only portfolios with returns equal to or above those of the minimum variance portfolio qualify as efficient. If portfolios are below the efficient frontier, their investments can be rearranged to attain more efficient positions with a lower risk and/or a higher yield. SFA (Aigner, Lovell, and Schmidt (1977), Meeusen and Van Den Broeck (1977)) and the presence of (exogenous) technological inefficiencies are commonly used to explain deviations from efficiency frontiers, since firms consistently struggle to exceed the “ideal” frontier when determining their output or cost frontiers (see Kumbhakar and Lovell (2003)). These inefficiencies have an impact on a company’s productivity and may cause the efficient frontier to change or scale. Both approaches are related to a regional economic context if we describe an economy as a portfolio of differently connected industries and integrate the idea of efficiency risk-return characteristics. While the SFA is the established econometric choice of many contributions in this respect (Chandra (2002, 2003), Kluge (2018)), the use of the MTP as the numerical simulation approach for optimal industry portfolios is not as common except the studies of Hafner (2016, 2019, 2020).

Conroy (1974, 1975) and Barth, Kraft, and West (1975) were the first to apply financial portfolio theory to a regional economic context and economic growth stability, while Chandra (2002, 2003) was among the pioneers to confirm convex growth-instability frontiers, using state-by-state data from the US and regional data from Europe. Regarding the existence of regional convex growth-instability frontiers of German federal states (Hafner (2016)), EU countries (Hafner (2019)) and Asian countries (Hafner (2020)), Hafner uses numerical simulations of GVA shares of different economic activities to determine whether industry structures in 2011 are efficient according to MPT. These studies show that rearranging GVA shares to form optimal industry portfolios increases gross value, and reduces economic instability. Moreover, SFA in Hafner (2019), Hafner (2020) shows for the sample of EU and Asian countries that getting more efficient is a combination of country characteristics and sector specifics, and that efficiency gains are inversely related to industrial diversification. By the same SFA methodology, Otsuka (2017)—based on the ideas of Otsuka, Goto, and Sueyoshi (2010)—analyze productive efficiency in Japan and show that efficiency gains are high in regional agglomerations of internationally competitive manufacturers, while efficiency gains are low in the Tokyo Metropolitan Area with diverse industrial structures. Focusing on the relationship between volatility and growth, Sahay and Goyal (2006) find that output growth in 17 Latin American countries was more volatile during the low growth episodes of 1970–2004. Bermúdez, Dabús, and González (2015) find the same negative effect in a panel of 17 Latin American countries between 1960 and 2011 using three-year averages. Moreover, Cavallo (2008) shows that trade openness had a stabilizing effect on output volatility using a cross-section of 77 countries (56 of which are non-OECD countries), which in turn increases economic growth rates. At the country level, Shepherd, Torres,
and Mendoza (2017) state that economic growth for Mexico is positively related to output volatility but negatively related to regional disparities in GDP across Mexican states—the latter being consistent with empirical findings in Rodríguez-Oreggia (2005).

Using the example of GVA shares of different economic activities in Latin America and its regional trade agreements (RTAs), this paper’s contribution is to show (i) how the optimal combinations of economic activities lead to efficiency gains, (ii) how efficiency gains are related to output volatility and industrial diversification, (iii) whether (and how) countries have been able to close the efficiency frontier gap, and (iv) how initial inefficiency relates to efficiency improvements across countries and sectors. To the best of our knowledge, there is no such empirical evidence for Latin America and its RTAs.

The paper is organized as follows. Section 2 outlines the theoretical framework of MPT and SFA, presents the cross-sectional dataset and gives a descriptive overview of Latin America’s GVA in 2011. Numerical MPT findings of optimal industry portfolios and SFA estimations of technical inefficiencies are discussed in section 3. Section 4 concludes.

2. Methods and data

The paper is a case study following the MPT and SFA approach of Hafner (2019, 2020). As a result, using MPT and SFA together allows us to examine not only convex growth-instability frontiers, but also the structure of countries’ industry portfolios and the relationship between efficiency gains and production volatility. We use the risk-return characteristics of economic activities to construct a cross-sectional dataset by defining an economy as a portfolio of differently related industries. The dataset is based on CEPAL (2016, 2020)’s national accounts from the Statistics and Indicator database for 19 Latin American countries.

2.1. Modern portfolio theory and stochastic frontier analysis

MPT, which was first introduced by Markowitz in 1952, states that efficient portfolios are typically created by strategically selecting various asset types. Only portfolios with returns equal to or higher than the minimum variance portfolio classify as efficient, according to Markowitz’s parabolic efficient frontier. If portfolios are below the efficient frontier, non-efficient portfolios can be rearranged by shifting investments—according to Figure 1—either to (a) lower risk positions with the same yield, or to (b) higher yield positions with the same risk:

\[
\begin{align*}
(a) \quad & SD(r_p)^{opt} \mid E(r_p) = \bar{\mu} \quad \text{or} \quad (b) \quad E(r_p)^{opt} \mid SD(r_p) = \bar{\sigma}, \quad (1)
\end{align*}
\]

where optimization of (a) or (b) depends on the risk attitude of the investor, which set predetermined range of values of \(\mu\) and \(\sigma\), respectively.

---

1See Hafner (2019, 2020) for a detailed description of both methodologies in a regional economic context searching for convex growth-instability frontiers.
SFA (Aigner et al. (1977), Meeusen and Van Den Broeck (1977)) and the presence of (exogenous) technological inefficiencies are commonly used to explain deviations from efficiency frontiers, since firms consistently struggle to exceed the “ideal” frontier when determining their output or cost frontiers. These inefficiencies have an impact on a company’s productivity and may cause the efficient frontier to change or scale. We estimate the productivity cost frontier model and its technological inefficiencies simultaneously, as Battese and Coelli (1995) did:

\[
\sigma_{ik} = \alpha + \beta_1 \mu_{ik} + \beta_2 u_{ik}^2 + u_{ik} + v_{ik} \quad i = 1, \ldots, n \text{ and } k = 1, \ldots, K, \tag{2}
\]

where \( u \) is a \( M+1 \)-dimensional vector of technical inefficiencies (i.e., \( M \) is the number of inefficiency control variables plus a constant) and \( \gamma \) is a vector of technology parameters. The idiosyncratic error term \( v \) has a zero mean and follows a normal distribution. All control variables are included in the inefficiency term \( u \) (i.e., technical inefficiencies). The efficient cost frontier model, according to Kluge (2018), is derived from MPT and captures risk and return as the only variables, while modifications cause deviations from the efficient frontier and should be included in the inefficiency term.

### 2.2. Cross-sectional dataset of Latin American countries

We use GVA shares of economic activities at the ISIC rev4 level (constant 2010 prices; US dollar) in 1990–2014 to measure the return and risk using the mean of constant price GVA growth rates (i.e., real growth rates) and their standard deviation, based on CEPAL (2016)’s national accounts from the Statistics and Indicators database for 19 Latin American countries (\( K = 19 \)). We identify six economic activities (\( n = 6 \)) to create a cross-
sectional dataset and use this dataset as the core for the numerical simulations of GVA shares with the MPT in mind and for the SFA to detect technical inefficiencies.\(^2\) To measure the mean growth rates for each activity \(i \ (i = 1, \ldots, 6)\) and country \(k \ (k = 1, \ldots, 19)\), we follow Lande (1994) and Chandra (2002) and regress the logarithm of real GVA on a time trend. For the variance-covariance matrix of the industry portfolio, we use the standard deviation measured by the variation of real growth rates against the mean and the correlation coefficients between economic activity growth rates within each region. As a result, the risk of industry portfolios is calculated by sectorial weighted averages in a cross-country setting—instead of a year-to-year basis in a panel, which is in line with the more recent literature on instability frontier analysis. Industry portfolios’ risk and return are then calculated by applying economic activities’ risk-return characteristics to GVA shares. To relate initial inefficiency to efficiency improvements, we use GVA shares of economic activities at the ISIC rev4 level (constant 2010 prices; US dollar) of the 2015–2018 period and compare them to 2011 industry portfolios.

Regarding the SFA, technical inefficiencies are captured as differences in the use of labor and are calculated by the (log) average annual employment ratio by activity for the 1990–2014 period.\(^3\) As control variables, we include the average annual growth rate of GDP per capita (constant 2010 prices; US dollar). Again, the data is taken from the CEPAL (2016) *Statistic and Indicators* database. As already discussed, economic theory suggests that industrial diversification makes countries and regions more stable and reduce output volatility (Imbs and Wacziarg (2003), Koren and Tenreyro (2013)). We follow Kluge (2018) and calculate an inverse Herfindahl index for each industry portfolio using the share of absolute values of GVA growth rates of each of its economic activities over their sum, and over the period 1991–2014.\(^4\) The inverse Herfindahl index takes values between 1 (concentration of 1 economic activity) and 6 (equal distribution of all 6 economic activities), reflecting the magnitude rather than the sign of economic activities’ contributions to GVA growth. The SFA estimation is based on this augmented cross-sectional dataset.

### 2.3. GVA of Latin American countries in 2011

We begin by measuring the risk and return of industry portfolios for the year 2011 by applying the historical risk-return characteristics of each economic activity to its 2011 GVA share. Countries are divided into four categories based on their regional trade agreements (RTA) membership (i.e., five Central American countries (“CACAM”), four Andean countries (“CAN”), five South American countries (“MERCOSUR”) and five non-RTA member countries (“NON-RTA”)). Total GVA is made up of six aggregated

---

\(^2\)GVA from national accounts by activity from CEPAL is broken down into nine economic activities with varying degrees of aggregation. Despite the fact that our cross-sectional dataset includes only 114 observations, we refrain from using the disaggregated dataset, as four out of six economic activities are presented in the aggregate, while two economic activities (i.e., “production” and “trade”) are broken down into subcategories (see Table A.1 in the appendix).

\(^3\)In choosing the most exogenous technical inefficiencies possible, labor and capital are the main input variables for firms to determine their production and cost functions. While the *Statistics and Indicators* database from CEPAL (2016) provides employment ratios by activity, no such disaggregated data is found for capital.

\(^4\)Note that we skip the first year (i.e., 1990) of which GVA shares of economic activities are available if we use growth rates for the calculation of the inverse Herfindahl index.
economic activities (“agriculture”, “production”, “construction”, “trade”, “financial activities”, and “service provision”).

Figure 2 show the price-adjusted mean growth rates and standard deviation for the 2011 industry portfolios, whereas Table A.2 and Tables A.4-A.6 in the appendix provide more detailed information about GVA shares of economic activities in Latin American countries. The scatterplot of Figure 2 shows the 2011 industry portfolios’ risk and return, respectively, for each country. The first thing we note is that there is no consistent trend in terms of GVA risk and return across countries and country groups. In some countries, a high risk is followed by higher growth rates, but not in others. The same is true for the other way round. However, in the case of countries belonging to MERCOSUR, four out of five countries report average price-adjusted mean growth rates below 3%, with average risk rates several percentage points (pp) higher than those of other RTA member countries. Specifically, Argentina and Venezuela report standard deviations of 5.57% and 6.06%, respectively, with growth rates lower than 3%. Moreover, industry portfolios of CACAM and CAN countries are widely diversified (see Table A.4 in the appendix), with GVA shares of more than 10% in the “production,” “trade,” “financial activities” and “service provision” sectors, while economic activities of MERCOSUR countries are more concentrated by the predominant sectors “production”, “trade” and “service provision” with GVA shares of 15% or more (see Table A.5 in the appendix), respectively.

Figure 2. Risk and Return of Latin American Countries, 2011.

---

5RTA membership countries are grouped according to RTA membership, while the grouping of sector categories follows the nomenclature of economic activities (WZ 2008, A10 with summaries) of the German Federal Statistical Office and the Statistics Offices of the federal states (DESTATIS (2008)). Note that the terms “economic activity” and “sector” are used interchangeably. Specific information is given in Table A.1 in the appendix.
3. Empirical findings of industry portfolios

By running numerical simulations of GVA shares data from CEPAL (2016), the empirical section investigates whether industry portfolios in 2011 were efficient according to MPT (2016). Finding they are not, we demonstrate how optimal combinations of economic activities contribute to higher income and greater output stability by rearranging the shares of economic activities and shifting industry portfolios to the (un)bounded productive frontier. Using CEPAL (2020) dataset from 2015–2018, we compare our 2011 numerical results to more recent industry portfolios and analyze whether countries have been able to close the efficiency frontier gap. As deviations from the efficient frontier are usually explained by the existence of technical inefficiency at the firm (and sector) level, we then turn to SFA to estimate the efficiency cost frontier and technical inefficiency model by using an augmented cross-sectional dataset from CEPAL (2016). While we are not able to derive specific policy suggestions, we finish with a discussion of the results when redefining a country’s industry portfolio and adjusting its sectorial mix of economic activities.

3.1. MPT findings of numerical simulation

We run numerical simulations of the 2011 GVA shares for each country and combination of economic activities to assess the unbounded efficient frontier as a collection of theoretically possible industry portfolios. As a result, a series of risk-return combinations emerges, with only those that have the lowest risk within a fixed range of returns qualifying for Markowitz’s (1952) parabolic efficient frontier.6 By rearranging economic activity shares according to equation (1), an industry portfolio below the (un)bounded productive frontier can be made efficient. To account for corner solutions and sectorial concentration, we follow Conroy (1974) and Board and Sutcliffe (1991) and calculate bounded efficiency gains by allowing a maximum deviation of either 20% or 50% from the 2011 GVA shares. Table 1 shows the distance from the (unbounded) efficient frontier in percentage points for (i) unbounded simulated weights, (ii) 50% bound on the 2011 weights and (iii) 20% bound on the 2011 weights.7 Based on their efficiency gains towards the (un)bounded efficiency frontier, Latin American countries are grouped according to RTA membership and ranked for optimal industry portfolios seeking (a) “reducing risk” for the same return or (b) “increasing return” for the same risk according to equation (1), respectively.

Efficiency gains from (a) “reducing risk”–Efficiency gains are highest with no bounds on simulation weights, varying between 3.2–0.11 pp for all Latin American

---

6In terms of methodology, we measure the effective frontier for each combination (i.e., out of six economic activities) by adjusting the weights in 0.01 pp increments. We record the risk-return characteristics of all weight combinations by choosing a risk averse attitude (i.e., optimization of (a) by equation (1)) and starting with a required return of 0% (i.e., minimum return). We then exclude those with an unfavorable risk and raise the necessary return by 0.01 percentage points until it reaches 10% (i.e., maximum return). We set a limit of maximum 50 percent of its GVA contribution because the sector “agriculture” contributes significantly to the GVA of some Latin American countries, and land for further use is small. Numerical simulations are performed for each country (i.e., out of 19 countries) by the use of the GAUSS matrix programming: http://www.aptech.com/products/gauss-mathematical-and-statistical-system/.

7The numerical simulation results from 50% or 20% bounds on 2011 industry weights are available on request from the author.
countries. Shifting Venezuela’s industry portfolio to the unbounded efficient frontier (i), for example, could reduce the GVA risk by 3.2 pp, while Nicaragua’s distance from the efficient frontier would be closed by 0.11 pp. Not surprisingly, the greater the restriction on a portfolio’s weight (i.e., (ii) and (iii)), the lower the efficiency gains, but these still account for 0.44 pp in the case of a 20% bound for Venezuela. While some countries are closer to the efficient frontier than others, there is (some) evidence of a common pattern between inefficiency and the degree of industrial diversification within and between country groupings. MERCOSUR member countries, for example, average relatively high efficiency gains in terms of reducing output volatility, while CACAM or CAN countries average relatively low efficiency gains. Moreover, the inverse Herfindahl index in four out of five MERCOSUR countries is very low compared to other RTA member countries. Countries classified as more concentrated, meaning a low inverse Herfindahl index, should attain higher efficiency gains from closing the efficiency frontier gap. The reverse is true for CACAM and CAN countries, where more diversified economies (with the exception of Nicaragua) are already closer to their efficient frontier and therefore show lower efficiency gains. At the country grouping level, we find the same pattern between inefficiency and

Table 1. Distance from Efficient Frontier.

| (a) reducing risk: Inv. Herf. | 2011 (i) | 2011 (ii) | 2011 (iii) | (b) increasing return: Inv. Herf. | 2011 (i) | 2011 (ii) | 2011 (iii) |
|-------------------------------|---------|---------|---------|-------------------------------|---------|---------|---------|
| Costa Rica                    | 4.555   | 1.02    | 0.68    | 0.30                          | 4.555   | 1.69    | 0.49    |
| El Salvador                   | 4.392   | 0.44    | 0.19    | 0.09                          | 4.532   | 1.68    | 0.55    | 0.26    |
| Guatemala                     | 4.681   | 0.35    | 0.21    | 0.11                          | 4.681   | 0.67    | 0.32    | 0.12    |
| Honduras                      | 4.532   | 0.27    | 0.18    | 0.12                          | 4.392   | 0.28    | 0.12    | 0.06    |
| Nicaragua                     | 4.110   | 0.11    | 0.12    | 0.09                          | 4.110   | 0.12    | 0.12    | 0.10    |
| CACAM                         | 4.454   | 0.44    | 0.28    | 0.14                          | 4.454   | 0.89    | 0.32    | 0.15    |
| Ecuador                       | 4.226   | 1.28    | 0.43    | 0.20                          | 4.226   | 0.63    | 0.20    | 0.09    |
| Colombia                      | 4.295   | 0.62    | 0.44    | 0.22                          | 4.295   | 0.48    | 0.23    | 0.10    |
| Peru                          | 4.497   | 0.23    | 0.14    | 0.07                          | 4.484   | 0.15    | 0.10    | 0.06    |
| Bolivia                       | 4.484   | 0.21    | 0.15    | 0.07                          | 4.497   | 0.12    | 0.08    | 0.04    |
| CAN                           | 4.376   | 0.58    | 0.29    | 0.14                          | 4.376   | 0.34    | 0.15    | 0.07    |
| Venezuela                     | 3.807   | 3.19    | 1.04    | 0.44                          | 3.807   | 1.23    | 0.54    | 0.22    |
| Argentina                     | 4.069   | 2.87    | 0.91    | 0.40                          | 4.531   | 0.74    | 0.25    | 0.09    |
| Paraguay                      | 4.159   | 1.43    | 0.93    | 0.42                          | 4.159   | 0.68    | 0.22    | 0.09    |
| Uruguay                       | 4.061   | 1.01    | 0.61    | 0.25                          | 4.069   | 0.46    | 0.20    | 0.08    |
| Brazil                        | 4.531   | 0.92    | 0.48    | 0.20                          | 4.061   | 0.40    | 0.23    | 0.10    |
| MERCOSUR                      | 4.125   | 1.89    | 0.79    | 0.34                          | 4.125   | 0.70    | 0.29    | 0.11    |
| Mexico                        | 4.483   | 1.72    | 0.69    | 0.27                          | 4.528   | 1.31    | 0.31    | 0.13    |
| Panama                        | 3.606   | 1.50    | 0.99    | 0.47                          | 4.153   | 1.08    | 0.60    | 0.28    |
| Dom. Rep.                     | 4.528   | 1.48    | 0.89    | 0.39                          | 4.483   | 1.06    | 0.40    | 0.16    |
| Cuba                          | 4.153   | 1.31    | 0.58    | 0.30                          | 4.606   | 0.81    | 0.48    | 0.22    |
| Chile                         | 4.787   | 0.87    | 0.35    | 0.15                          | 4.787   | 0.64    | 0.35    | 0.15    |
| NON-RTA                       | 4.311   | 1.38    | 0.70    | 0.31                          | 4.311   | 0.98    | 0.43    | 0.19    |

Notes: Efficiency gains in percentage points (pp) from optimal industry portfolios seeking (a) reduced risk for the same return and (b) increased returns for the same risk are calculated for (i) unbounded simulated weights, (ii) 50% bound on the 2011 weights and (iii) 20% bound on the 2011 weights. The inverse Herfindahl index takes values between 1 (concentration of one sector) and 6 (equal distribution of all six economic activities within industry portfolios).

Source: Annual national accounts of Latin American countries by the CEPAL (2016) Statistics and Indicators database (constant 2010 prices, millions of dollars), author’s calculation.
industrial diversification by taking the group mean. However, this evidence is not found in the case of the remaining NON-RTA country group, except Chile, which shows a relatively high degree of industrial diversification and at the same time relatively low efficiency gains.

Efficiency gains from (b) “increasing returns”.—Similarly, unbounded efficiency gains (i) vary by 1.7–0.12 pp for all Latin American countries, with Costa Rica ranking at the top and, once again, Nicaragua, along with Peru, coming in closest to their efficient frontier. Again, bounded efficiency gains (i.e., (ii) and (iii)) are lower, but the countries’ rankings within country groups are comparable to unbounded efficiency gains. Regarding the negative relationship between efficiency gains and industrial diversification, there is no such evidence for RTA member countries in this case. The three most diversified CACAM countries, for example, have higher efficiency gains than the three most concentrated MERCOSUR countries in seeking to maximize the return of GVA. In the case of NON-RTA countries, the Dominican Republic and Chile, both ranked with relatively high inverse Herfindahl index, rank at the top and bottom in terms of efficiency gains. If we return to the country grouping level and take once again the group mean, we see that efficiency gains in terms of higher economic growth rates are quite comparable between CACAM and MERCOSUR despite their difference in the degree of industrial diversification.

Summary I.—Depending on whether optimal industry portfolios are obtained by (a) “reducing risk” or (b) “increasing return,” optimization rating changes, but not to a large degree. This means that closing the gap against the efficiency frontier benefits countries on average regardless of whether output instability is reduced or GVA growth rates are increased; however, industrial diversification is only closely related to efficiency gains when GVA risk is minimized. In fact, numerical results show that efficiency gains are on average lower for countries with a higher degree of industrial diversification when it comes to reducing output volatility.

3.2. Efficiency frontier gap

We analyze the progress (or lack of therefore) in moving toward the efficiency frontier over time by comparing efficiency gains of 2011 industry portfolios to those of more recent industry portfolios (i.e., of the 2015–2018 period) and analyze whether countries have been able to close the efficiency frontier gap. Table 2 shows the distance from the unbounded efficient frontier (i) in pp for 2018 and (an average of) 2015–2018, and the difference (diff) in efficiency gains in pp compared to those of 2011 industry portfolios. Note that countries are able to close the efficiency frontier gap if the difference is positive for optimal industry portfolios aiming at both (a) “reducing risk” or (b) “increasing return”; getting more efficient, potential efficiency gains are lower compared to those of 2011.

Closing the efficiency frontier gap by (a) “reducing risk”.—Unbounded efficiency gains (i) from (a) “reducing risk” vary between 2.8–0.2 pp for both 2018 and (an average of) 2015–2018 industry portfolios. Countries’ rankings within country groups are comparable to Table 1. For most of Latin American countries, efficiency gains are lower and
Table 2. Closing the Efficiency Frontier Gap.

|                  | 2018  | 2015–2018 | (a) reducing risk: | (i) diff. | (i) diff. | (b) increasing return: | (i) diff. | (i) diff. |
|------------------|-------|-----------|---------------------|-----------|-----------|------------------------|-----------|-----------|
| Costa Rica       | −0.89 | 0.12      | −0.90               | 0.11      |           | Costa Rica             | 1.50      | 0.18      |
| El Salvador      | −0.37 | 0.08      | −0.39               | 0.06      |           | Honduras               | 1.45      | 0.23      |
| Guatemala        | −0.28 | 0.07      | −0.28               | 0.07      |           | Guatemala              | 0.66      | 0.02      |
| Honduras         | −0.22 | 0.05      | −0.22               | 0.05      |           | El Salvador            | 0.30      | −0.02     |
| Nicaragua        | −0.20 | −0.08     | −0.29               | −0.18     |           | Nicaragua              | 0.21      | −0.09     |
|                  | −0.39 | 0.05      | −0.42               | 0.02      |           | CACAM                  | 0.82      | 0.06      |
| Ecuador          | −1.21 | 0.05      | −1.23               | 0.02      |           | Ecuador                | 0.64      | −0.01     |
| Colombia         | −0.45 | 0.17      | −0.45               | 0.17      |           | Colombia               | 0.35      | 0.14      |
| Peru             | −0.22 | 0.01      | −0.22               | 0.01      |           | Bolivia                | 0.16      | −0.01     |
| Bolivia          | −0.22 | −0.01     | −0.21               | −0.01     |           | Peru                   | 0.12      | 0.00      |
| CAN              | −0.52 | 0.05      | −0.53               | 0.05      |           | CAN                    | 0.32      | 0.03      |
| Venezuela        | −2.32 | 0.87      | −2.73               | 0.47      |           | Venezuela              | 1.08      | 0.15      |
| Argentina        | −2.80 | 0.07      | −2.79               | 0.09      |           | Brazil                 | 0.68      | 0.06      |
| Paraguay         | −0.73 | 0.70      | −0.73               | 0.70      |           | Paraguay               | 0.63      | 0.05      |
| Uruguay          | −0.95 | 0.06      | −1.00               | 0.02      |           | Argentina              | 0.42      | 0.03      |
| Brazil           | −0.83 | 0.09      | −0.83               | 0.10      |           | Uruguay                | 0.37      | 0.02      |
|                  | −1.53 | 0.36      | −1.61               | 0.27      |           | MERCOSUR               | 0.64      | 0.06      |
| Mexico           | −1.73 | −0.01     | −1.73               | −0.01     |           | Dom. Rep.              | 1.12      | 0.19      |
| Panama           | −2.76 | −1.26     | −2.74               | −1.24     |           | Cuba                   | 1.32      | −0.23     |
| Dom. Rep.        | −1.35 | 0.13      | −1.30               | 0.18      |           | Mexico                 | 0.97      | 0.09      |
| Cuba             | −1.66 | −0.35     | −1.58               | −0.27     |           | Panama                 | 0.96      | −0.15     |
| Chile            | −0.84 | 0.04      | −0.85               | 0.02      |           | Chile                  | 0.61      | 0.03      |
|                  | −1.67 | −0.29     | −1.64               | −0.26     |           | NON-RTA                | 1.00      | −0.01     |

Notes: Efficiency gains in percentage points (pp) from optimal industry portfolios of 2018 and (an average) of 2015–2018 seeking (a) reduced risk for the same return and (b) increased returns for the same risk are calculated for (i) unbounded simulated. Difference in efficiency gains between industry portfolios of 2011 and 2018 or (an average of) 2015–2018 is in pp (taking rounding differences into account).

Source: Annual national accounts of Latin American countries by the CEPAI (2020) Statistics and Indicators database (constant 2010 prices, millions of dollars), author’s calculation.

Therefore countries getting more efficient closing the gap to their efficient frontier if compared to 2011 (i.e., comparing column (i) of Table 2 with Table 1). MERCOSUR countries, which are more concentrated with a relatively low inverse Herfindahl index, still average relatively high efficiency gains in terms of reducing output volatility, while the more diversified CACAM and CAN countries have relatively low efficiency gains. In particular, MERCOSUR countries shifted their industry portfolio closer to their efficiency frontier gap and reduced their output volatility on average by 0.36 pp for 2018 or 0.27 pp for the 2015–2018 period (according to column (diff)). By contrast, potential efficiency gains since 2011 are on average moderate for CACAM and CAN countries (i.e., between 0.05 pp and 0.02 pp by column (diff), respectively) as these countries have been already close to their efficiency frontier by 2011. However, Nicaragua and Bolivia, for example, shifted away as their output volatility increased slightly. No such evidence is found in the case of the remaining NON-RTA country group, where some countries as Chile, which shows a relatively high degree of industrial diversification, got closer to its efficiency frontier, while non-diversified countries as Panama and Cuba lost ground by drifting further away and increased their efficiency frontier gap between 1.3–0.27 pp, respectively.
Closing the efficiency frontier gap by (b) “increasing return”—Unbounded efficiency gains (i) from (b) “increasing return” vary by 1.52–0.12 pp for all Latin American countries for industry portfolios of 2018 or (an average of) 2015–2018, respectively. Taking the group mean at the country grouping level, we can see that despite their differences in the degree of industrial diversification, efficiency gains in terms of higher economic growth rates are very comparable between CACAM and MERCOSUR. MERCOSUR countries, for example, have been able to close the efficiency frontier gap on average by 0.06 pp with Venezuela ranking at the top and Argentina, along with Uruguay, ranking at the bottom with (almost the same) realized efficiency gains if we compare 2011 industry portfolios to those of 2018 (i.e., column (diff)). By the same way, CACAM countries average efficiency gains of 0.06 pp, three out of five have been able to reduce their efficiency gap. Honduras and Costa Rica, for example, closed the efficiency frontier gap with 0.23 pp and 0.18 pp respectively, while Nicaragua, which was already close to the efficient frontier by 2011, drifted (slightly) away from their efficient frontier. No such evidence is found for CAN countries (except Columbia, which indeed realized efficiency gains by 0.14 pp) as their efficiency frontier gap is the same as in 2011. Again, numerical results for Non-RTA member countries are heterogeneous, where some countries like the Dominican Republic have been able to reduce the efficiency gap, while others like Cuba and Panama shifted away from their efficiency frontiers.

Summary II.—Comparing the numerical results of 2011 industry portfolios with those of more recent industry portfolios (i.e., of the 2015–2018 period), countries have been able to close the efficiency frontier gap and captured efficiency gains in terms of lower output volatility and higher GVA growth rates. With the aim of minimizing GVA risk, diversified countries like CACAM or CAN member countries, which have been already closer to their efficiency frontier, realized lower efficiency gains compared to more concentrated countries of MERCOSUR with higher efficiency gains. However, no such relationship between industrial diversification and realized efficiency gains is found if countries aim to increase GVA growth rates.

3.3. SFA estimation of technical inefficiencies

Estimation results from SFA are based on the risk-return characteristics of six aggregated sectors in a cross-sectional setting of 19 countries.8 We begin by estimating the stochastic frontier using equation (2) without specifying technical inefficiency (i.e., \( u = 0 \)) and show the results as a benchmark for measuring efficiency in Figure 3. We then turn to the estimation of the efficiency cost model and the inefficiency term. Table 3 shows the estimation results of equation (2) for different model specifications, including technical inefficiency and/or dummies for sectors, countries and country groupings. Results are given for the convexity of risk with respect to its yield (i.e., efficient cost frontier model; (i)-(vii)) and for the determinants of inefficiency (i.e., inefficiency model; (iv)-(vii)).

---

8Any stochastic frontier model must be calculated technically by taking logs. We measure the standard deviation by comparing the variation of real growth rates against their mean, which is obtained by regressing the logarithm of real gross value added on a time trend (of the 1990–2014 period). As measures of technical inefficiencies and control variables, we include the (log) average annual employment ratio by economic activity, the average annual growth rate of GDP per capita by country and an inverse Herfindahl index for measuring industrial diversification. As a result, equation (2) is estimated using log averages and the STATA modules “frontier” and “sfcross” (see Belotti et al., 2013).
Figure 3. Stochastic Frontier for Latin American Countries.

Benchmark for measuring efficiency. Refraining from including technical inefficiencies, Figure 3 shows the distance from the efficiency frontier for both country groupings (in the left panel) and sector categories (in the right panel), whereas Table A.3 in the appendix shows the average efficiency gains in pp. First of all, the left panel shows no common inefficiency pattern regardless of the country group to which the sector belongs, except for CACAM countries, where efficiency gains are on average lowest and the degree of industrial diversification is highest. The key sectors “service provision” and, to a lesser degree, “financial activities” are nearest to the efficiency frontier in the right panel, while “construction” is the furthest away. As a result, countries with higher shares of the dominant sectors “service provision” and “financial activities” should be more efficient than others, while countries with high shares of the “construction” sector should avoid using it to form optimal industry portfolios due to the unfavorable risk-return profile.

Estimation of efficient cost frontier. Starting with the baseline estimation of the efficient cost frontier model without dummies (i.e., estimation model (i) and as shown in Figure 3), a likelihood ratio test of the inefficiency term (i.e., H₀: 𝑢 = 0) at the bottom of Table 3 shows that there is significant inefficiency compared to an OLS estimation. Furthermore, the standard deviation of the inefficiency term 𝑢 far outweighs that of the idiosyncratic error 𝑣 (the lambda ratio is 3.33E+07). This is even more proof in favor of the efficient cost frontier model. The convexity of risk with respect to its yield is confirmed by estimation, both in terms of sign and significance. Estimates from the efficient cost frontier model (i.e., (ii)-(iii) where sector dummies are paired with country or country grouping dummies)
Table 3. Empirical Results from SFA.

|                | (i)      | (ii)     | (iii)    | (iv)     | (v)      | (vi)     | (vii)    |
|----------------|----------|----------|----------|----------|----------|----------|----------|
| **Efficient cost frontier model: Risk (a)** |          |          |          |          |          |          |          |
| Growth rate   | \(-0.935^{***}\) | \(-1.587^{***}\) | \(-1.589^{***}\) | \(-0.935^{***}\) | \(-0.430\) | \(-0.935^{***}\) | \(-0.439\) |
| \((\mu)\)    | 0.0002   | 0.5908   | 0.4241   | 0.0001   | 0.4484   | 0.0001   | 0.4546   |
| Growth rate   | 14.146^{***} | 21.619^{***} | 22.932^{***} | 14.146^{***} | 10.216*  | 14.146^{***} | 10.318*  |
| \((\mu')\)   | 0.0036   | 6.1079   | 4.6399   | 0.0012   | 5.2812   | 0.0013   | 5.3808   |
| Constant      | 0.025^{***} | 0.036^{***} | 0.031^{***} | 0.025^{***} | 0.012    | 0.025^{***} | 0.012   |
| Dummies       | no       | yes\(^{ab}\) | yes\(^{ac}\) | no       | yes\(^a\) | no       | yes\(^a\) |
| **Inefficiency model: Inefficiency (u)** |          |          |          |          |          |          |          |
| Labor         | \(-1.020^{***}\) | \(-0.984^{***}\) | \(-1.022^{***}\) | \(-0.972^{***}\) |          |          |          |
|               | 0.1955   | 0.2558   | 0.1958   | 0.2588   |          |          |          |
| Ind. Div.     | \(-8.314^{***}\) | \(-3.714^{***}\) | \(-1.979^{***}\) | \(-3.698^{***}\) |          |          |          |
|               | 2.1932   | 0.7526   | 0.5103   | 0.7724   |          |          |          |
| GDP . p. c.   | 11.759   | 6.241    | 12.013   | 6.105    |          |          |          |
|               | 7.7501   | 8.9510   | 7.6984   | 8.9259   |          |          |          |
| Constant      | 8.241^{**} | 11.202^{**} | 4.640^{**} | 11.110^{**} |          |          |          |
|               | 3.2888   | 3.3231   | 2.3079   | 3.4160   |          |          |          |
| **Idiosyncratic error term** |          |          |          |          |          |          |          |
| Correlation   |          |          |          |          | \(-3.010\) | 1.853    |          |
|               |          |          |          |          | 1968.7850 | 2.4861   |          |
| Constant      |          |          |          |          | \(-39.448\) | \(-10.329^{***}\) |          |
|               |          |          |          |          | 533.8511 | 0.9573   |          |
| SD of V       | 1.75E-09 | 2.16E-09 | 6.64E-03 |          |          |          |          |
| SD of U       | 0.0584   | 0.0359   | 0.0434   |          |          |          |          |
| **Inefficiency Test** |          |          |          |          |          |          |          |
| \(H_0: \mu=0\) | 56.36    | 59.19    | 31.62    |          |          |          |          |
| p-value       | 0        | 0        | 0        |          |          |          |          |
| No. of obs.:  | 114      | 114      | 114      | 102      | 102      | 102      | 102      |

Notes: Estimation of the stochastic frontier includes unreported sector dummies (a), country dummies (b) and country grouping dummies (c). Standard errors are reported in italics. * (**) [***] denotes that the coefficient is significantly different from zero at the 10% (5%) [1%] level.

Source: Annual national accounts of Latin American countries from CEPAL (2016) Statistics and Indicators database (constant 2010 prices, millions of dollars), author’s calculation.

confirm the presence of inefficiencies—both by the likelihood ratio test of the inefficiency term and by the lambda ratio—and the risk-return convexity.

Taking into account the (relatively low) number of observations and incorporating inefficiency determinants, we refrain from including the full set of dummies and concentrate on sector dummies to estimate the efficient cost frontier model and the inefficiency model (i.e., (iv)-(vii) with or without sector dummies).\(^9\) The results of the convex growth-instability frontiers are still significant at least at the 10% level—i.e., a significance level of (v) and (vii) are shown in the estimates to be slightly above 5%—with the expected sign. Estimates show no major change in sign and significance for the inefficiency model regardless of whether or not sector dummies are included. Simultaneous estimation of the inefficiency model shows that differences in the log average employment ratios are highly significant in explaining the distance from the efficient frontier. Higher employment ratios are strongly correlated with more efficient combinations of economic activities (and therefore are negatively related to distance). Moreover, industrial

\(^9\)Participating in different RTAs may relax or impose sectorial constraints on member countries’ (average) GVA shares of economic activities. Including country-grouping dummies to model (v) and (vii), for example, coefficients remain almost unchanged in terms of sign, magnitude and significance, and estimates still confirm convex growth-instability frontiers. Hence, inefficiency exists across sectors and RTA membership.
diversification controls significantly for locations other than the efficient frontier. The coefficient of industrial diversification is negative and significant, which is consistent with the findings of Kluge (2018) and Hafner (2019, 2020). This means that more diversified industry portfolios are closer to the efficient frontier. It turns out, that controlling for GDP per capita growth rates (with an insignificant coefficient) has no explanatory influence on countries’ distance from their efficient frontiers. Running the same regressions but taking heteroscedasticity into account (i.e., (vii)), we arrive at comparable same results in terms of signs, magnitude and significance for both the efficient cost frontier model and inefficiency model.\(^\text{10}\)

*Summary III.*—Estimates confirm convex growth-instability frontiers for Latin America countries, where inefficiencies exist across sectors and their RTA membership. Higher employment ratios and diversified economies (but not income differences) are strongly correlated with more efficient combinations of economic activities (and therefore are negatively related to distance). This brings countries’ industry portfolios closer to their efficient frontier disclosing the relationship between initial inefficiency and efficiency improvements. The results are robust for different model specifications.

### 3.4. Lessons and limitations

There is a wide variation in governance structure and policy-making across the countries used in the dataset. While we are not able to derive specific policy suggestions, some common conclusions and limitations for the applicability might be of help. For most of Latin American countries, there is progress in moving toward the efficiency frontier. Numerical results on the one hand show that Latin American countries closed the gap to their efficient frontier, whereas efficiency improvements differ according to RTA membership. In terms of reducing output volatility, more concentrated countries like MERCOSUR countries, for example, still average relatively high (potential) efficiency gains than more diversified CACAM and CAN countries, which have been already closer to their efficiency frontier. SFA results on the other hand point to higher employment ratios and the sectorial mix of economic activity to increase efficiency. Predominant sectors like “service provision” and “financial activities,” are closest to the efficient frontier, while “construction” is the farthest. Efficiency improvements by restructuring of economic activity, however, is costly and often limited in scale, and changes the risk-return characteristics of economic activities and income-stabilization potential. Income distortions due to disinvestment in some sectors must be offset by additional demand from other domestic sectors and foreign markets. While efficiency improvements might be more likely to be achieved in the production (and supply) of public and financial services, adjusting other sectors, like the production of primary goods, for example, seems to be difficult, even in the long run, with implications difficult to estimate. The three top trading partners in 2019 of Central America 6 (i.e., CACAM countries plus Panama), Andean countries (i.e., CAN countries minus Bolivia), and MERCOSUR 4 (i.e., MERCOSUR countries minus Venezuela) are the USA, EU27, and China. Exports to the EU27, for example, consist mainly of primary products (according to SITC Rev. 3 product groups) that make up

\(^{10}\)Like in the case of the degree of industrial diversification, we use the absolute values of the correlation coefficients between economic activities and calculate the average absolute correlation of each economic activity.
4. Conclusion

The paper is a case study of the risk-return characteristics of Latin Americas’ economic activities relying on the approach and methodology of Hafner (2019), Hafner (2020). We provide evidence of convex growth-instability frontiers for 19 Latin American countries using GVA shares by economic activity over the 1990–2014 period. Taking their industry structure as they stand in 2011, numerical simulations show that industry portfolios were below the efficient frontier defined by Markowitz (1952), and that rearranging the shares of economic activities leads to efficiency gain. We find that reducing output volatility leads to efficiency gains that are on average higher for countries with a concentration of economic activities—as predicted by the economic theory: MERCOSUR countries with a low degree of industrial diversification average relatively high efficiency gains, while the reverse is true for CACAM and CAN countries, where more diversified economies are already closer to the efficient frontier. Comparing the numerical results of 2011 industry portfolios with efficiency gains of more recent industry portfolios, Latin American countries have been able to close the efficiency frontier gap since 2011 and captured efficiency gains in terms of lower output volatility and higher GVA growth rates. Minimizing GVA risk, for example, shows that diversified countries like CACAM or CAN member countries, which have been already close to their efficiency frontier by 2011, realized lower efficiency gains compared to more concentrated countries of MERCOSUR with higher efficiency gains.

The convex growth-instability frontiers are confirmed by SFA estimates, which point to disparities in employment ratios and the degree of industrial diversification as the key sources of inefficiency. As a result, higher employment levels and economic diversification are closely linked to more efficient combinations of economic activities, narrowing the distance to the efficient frontier. With the exception of CACAM countries—which average the lowest efficiency gains and the highest degree of industrial diversification—there is no common pattern of inefficiency regardless of whether or not countries belong to a certain country grouping. Moreover, the predominant sectors from the numerical simulation, “service provision” and “financial activities,” are closest to the efficient frontier, while “construction” is the farthest. Hence, countries with a high share of the sectors “service provision” and “financial activities” should be more efficient than others.

Industry portfolio optimization in a regional economic context differs to Markowitz’ asset allocation of investors seeking to maximize asset portfolios’ return or minimize its risk. Restructuring of economic activity, for example, is costly and often limited in scale, even in the longer term, and changes the risk-return characteristics of economic

---

11Regional and country trade statistics with the EU are provided by the Directorate General for Trade of the European Commission: https://ec.europa.eu/trade/policy/countries-and-regions/.
activities and the potential for income stabilization. When it comes to redefining industry policies, the optimal portfolio of the industry may look different but is still based on the main idea of strategic asset allocation to strengthen industries with a favorable risk-return profile that promotes economic growth in the GVA and reduces economic instability. For a better understanding of how to structure optimal regional industry portfolio and of the kind (and extend) of efficiency gains that can be obtained a result of the regional income-stabilization potential, we need to use more disaggregated data for regions and industries and to apply a combination of different methods (i.e., like MPT, SFA, data envelopment analysis (DEA), and input-output analysis). Using these methodological options, (and in particular DEA as an alternative method to analyze efficiency frontiers) and comparing the results gives us a full(er) picture of the relationship between (initial) inefficiency and efficiency improvements. This way, we are able to gain insights into the risk-return characteristics of regional industries and their potential for output stability and economic growth. Closely related, if we assess the link between economic performance and the role of policy-making regimes as in Chandra and Rudra (2015), we can account for the wide variation in the governance structure in redefining the country’s industrial portfolio and adjusting its sectoral mix of economic activities.

**Disclosure statement**

No potential conflict of interest was reported by the author(s).

**Notes on contributor**

_Prof. Dr. Kurt A. Hafner_ is a professor for economics at the Heilbronn University, Germany.

**References**

Aigner, D., Lovell, C., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. _Journal of Econometrics_, 6(1), 21–37.

Barth, J., Kraft, J., & West, P. (1975). A Portfolio Theoretical Approach to Industrial Diversification and Regional Employment. _Journal of Regional Science_, 15(1), 9–15.

Battese, G. E., & Coelli, T. J. (1995). A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel Data. _Empirical Economics_, 20(2), 325–332.

Belotti, F., Silvio D., Giuseppe I., & Vincenzo A. (2013). Stochastic Frontier Analysis using STATA. _Stata Journal_, 13(4), 718–758.

Bermúdez, C., Dabús, C. D., & González, G. H. (2015). Reexamining the Link between Instability and Growth in Latin America: A Dynamic Panel Estimation using K-Median Clusters. _Latin American Journal of Economics_, 52(1), 1–23.

Board, J., & Sutcliffe, C. (1991). Risk and Income Tradeoffs in Regional Policy: A Portfolio Theoretic Approach. _Journal of Regional Science_, 31(2), 191–210.

Cavallo, E. A. (2008). Output Volatility and Openness to Trade: A Reassessment. _Economia_, 9(1), 105–138.

CEPAL (2016) _Statistics and Indicators Database. Data from 1990-2014_. [http://estadisticas.cepal.org/cepalstat/WEB_CEPALSTAT/estadisticasIndicadores.asp](http://estadisticas.cepal.org/cepalstat/WEB_CEPALSTAT/estadisticasIndicadores.asp). Last accessed: 15 December 2016.
CEPAL (2020) Statistics and Indicators Database. Data from 2015-2018. http://estadisticas.cepal.org/cepalstat WEB_CEPALSTAT/estadisticasIndicadores.asp. Last accessed: 02 July 2020.

Chandra, S. (2002). A Test of the Regional Growth-Instability Frontier Using State Data. Land Economics, 78(3), 442–462.

Chandra, S. (2003). Regional Economy Size and the Growth-Instability Frontier: Evidence from Europe. Journal of Regional Science, 43(1), 95–122.

Chandra, S., & Rudra, N. (2015). Reassessing the Links between Regime Type and Economic Performance: Why Some Authoritarian Regimes Show Stable Growth and Others Do Not. British Journal of Political Science, 45(2), 253–285.

Conroy, M. E. (1974). Alternative Strategies for Regional Industrial Diversification. Journal of Regional Science, 14(1), 31–46.

Conroy, M. E. (1975). The Concept and Measurement of Regional Industrial Diversification. Southern Economic Journal, 41(3), 492–505.

DESTATIS (2008) Nomenclature of Economic Activities – WZ 2008 A10 with Summary. https://www.destatis.de/DE/Methoden/Klassifikationen/GueterWirtschaftsklassifikationen/Content75/KlassifikationWZ08.html. Last accessed: 02 July 2020.

Hafner, K. A. (2016). Regional Industrial Diversification: Evidence from German Gross Value Added. Review of Regional Research, 36(2), 169–193.

Hafner, K. A. (2019). Growth-instability frontier and industrial diversification: Evidence from European Gross Value Added. Papers in Regional Science, 98(2), 799–824.

Hafner, K. A. (2020). Diversity of Industrial Structure and Economic Stability: Evidence from Asian Gross Value Added. Asia-Pacific Journal of Regional Science, 4(2), 413–441.

Imbs, J., & Wacziarg, R. (2003). Stages of Diversification. American Economic Review, 93(1), 63–86.

Kluge, J. (2018). Sectoral Diversification as Insurance against Economic Instability. Journal of Regional Science, 58(1), 204–223.

Koren, M., & Tenreyro, S. (2013). Technological Diversification. American Economic Review, 103(1), 378–414.

Kumbhakar, S. C., & Lovell, C. K. (2003). Stochastic Frontier Analysis. U K: Cambridge University Press.

Lande, P. S. (1994). Regional Industrial Structure and Economic Growth and Instability. Journal of Regional Science, 34(3), 343–360.

Markowitz, H. (1952). Portfolio Selection. The Journal of Finance, 7(1), 77–91.

Meese, W., & Van Den Broeck, J. (1977). Efficiency Estimation from Cobb–Douglas Production Functions with Composed Error. International Economic Review, 18(2), 435–444.

Otsuka, A. (2017). Regional Determinants of Total Factor Productivity in Japan: Stochastic Frontier Analysis. The Annals of Regional Science, 58(3), 579–596.

Otsuka, A., Goto, M., & Sueyoshi, T. (2010). Industrial agglomeration effects in Japan: Productive efficiency, market access, and public fiscal transfer. Papers in Regional Science, 89(4), 819–839.

Rodriguez-Oreggia, E. (2005). Regional Disparities and Determinants of Growth in Mexico. The Annals of Regional Science, 39(2), 207–230.

Sahay, R., & Goyal, R. (2006) Volatility and Growth in Latin America: An Episodic Approach. IMF Working Paper WP/06/287.

Shepherd, D., Torres, R. M., & Mendoza, M. A. (2017). Economic Growth and Regional Integration in Mexico. Economic Issues, 22(1), 89–110.
Table A.1 Sector Categories and Country Groupings

| WZ 2008: A*10 with summaries | Sector Category: |
|-------------------------------|-----------------|
| A: Agriculture, hunting and forestry; fishing | “Agriculture” |
| B-E: Industry, excluding construction | “Production” |
| F: Construction | “Construction” |
| G-J: Trade, hotels, transport, information and communications | “Trade” |
| K-N: Financial and insurance, real-estate, renting and business activities | “Financial activities” |
| O-T: Public and private service, other service activities | “Service provision” |

| RTA Member Countries |
|----------------------|
| Central American Common Market: four founding members in 1960 (i.e., Guatemala, Honduras, El Salvador and Nicaragua) and 1961-enlargement country Costa Rica. |
| Andean Community of Nations founded in 1969 by Bolivia, Colombia, Ecuador and Peru |
| Southern Common Market founded in 1991 by Argentina, Brazil, Paraguay, Uruguay and Venezuela |
| Non-regional trade agreement member countries: Chile, Cuba, Dominical Republic, Mexico and Panama |

Notes: GVA from national accounts by activity from CEPAL are broken down to nine economic activities and vary regarding their degree of aggregation. Four out of six economic activities (“agriculture,” “construction,” “financial activity” and “service provision”) are provided as an aggregate, while two economic activities (“production” and “trade”) are broken down into subcategories. In particular, GVA for “industry, excluding construction” (i.e., B-E at the ISIC rev4 level) is provided for “mining and quarrying” (B), “manufacturing” (c) and “electricity, gas and water supply” (D+E). The same applies to “trade, hotels, transports, information and communication” (i.e., G-J at the ISIC rev4 level) with two subcategories of data available: “wholesale and retail trade” (G) and “transport, storage and communications” (H-J). Source: Classification of economic activities according to the German Federal Statistical Office and the Statistical Offices of the federal states (DESTATIS, 2008). Country groupings according to Latin America RTA membership.

Table A.2. Gross Value added for Latin American Countries, 2011

| | CACAM Countries | CAN Countries | MERCOSUR Countries | NON-RTA Countries |
|---|---|---|---|---|
| | GVA | Share | GVA | Share | GVA | Share | GVA | Share |
| All sectors | 122,469 | 0.03 | 511,971 | 0.11 | 2,621,857 | 0.56 | 1,408,488 | 0.30 |
| Agriculture | 13,135 | 0.11 | 39,352 | 0.08 | 145,972 | 0.06 | 46,383 | 0.03 |
| Production | 26,256 | 0.21 | 146,824 | 0.29 | 612,268 | 0.23 | 375,602 | 0.27 |
| Construction | 5,880 | 0.05 | 40,158 | 0.08 | 169,226 | 0.06 | 112,957 | 0.08 |
| Trade | 31,117 | 0.25 | 109,273 | 0.21 | 573,028 | 0.22 | 366,160 | 0.26 |
| Fin. Activities | 24,195 | 0.20 | 86,479 | 0.17 | 383,881 | 0.15 | 299,016 | 0.21 |
| Service Provision | 21,887 | 0.18 | 89,887 | 0.18 | 737,483 | 0.28 | 208,369 | 0.15 |

Source: Annual national accounts of Latin American countries from CEPAL (2016) Statistics and Indicators database (constant prices, millions of dollars), author’s calculation.

Table A.3. Stochastic Frontier Analysis; country grouping and sector categories

| Efficiency gains | Efficiency gains | Herfindahl |
|------------------|------------------|------------|
| Mean | Std | Min | Max | Mean | Std | Min | Max | Mean | Std |
| Agriculture | 3.88 | 2.99 | 0.53 | 7.74 | 4.43 | 0.00 | 11.74 | 26.06 | 4.454 | 0.195 |
| Production | 3.12 | 1.38 | 0.66 | 6.92 | 4.76 | 0.41 | 6.92 | 10.17 | 4.376 | 0.118 |
| Construction | 10.27 | 5.74 | 2.82 | 26.06 | 5.08 | 0.06 | 5.74 | 16.67 | 4.125 | 0.235 |
| Trade | 3.51 | 2.35 | 0.57 | 8.78 | 4.46 | 0.00 | 8.78 | 19.66 | 4.311 | 0.406 |
| Fin. Activities | 2.35 | 1.64 | 0.00 | 5.92 | 4.46 | 0.00 | 5.92 | 19.66 | 4.311 | 0.406 |
| Serv. Provision | 1.48 | 1.42 | 0.00 | 5.24 | 4.46 | 0.00 | 5.24 | 19.66 | 4.311 | 0.406 |

Notes: Efficiency gains in percentage points (pp) from estimating efficient frontier without specification of inefficiency term and not including sector and country dummies. Last column shows the mean and standard deviation of the inverse Herfindahl index for country groupings with values between 1 (concentration of one sector) and 6 (equal distribution of all six economic activities within industry portfolios). Source: Annual national accounts of Latin American countries from CEPAL (2016) Statistics and Indicators database (constant 2010 prices, millions of dollars), author’s calculation.
Table A.4. Actual vs. Optimal Portfolio for CACAM and CAN Member Countries, 2011.

| Country        | Return  | Risk    | Return  | Risk    | Return  | Risk    |
|----------------|---------|---------|---------|---------|---------|---------|
|                | 2011    | Opt. Port. | 2011    | Opt. Port. | 2011    | Opt. Port. |
| Costa Rica (CR) | 4.67%   | 2.26%   | 4.68%   | 2.12%   | 3.74%   | 1.03%   |
| El Salvador (SLV) | 6.36% | 2.27%   | 2.53%   | 1.98%   | 4.08%   | 1.02%   |
| Guatemala (GTM)  | 2.54%   | 1.90%   | 2.53%   | 1.90%   | 3.74%   | 1.03%   |

|                | 2011    | Opt. Port. | 2011    | Opt. Port. | 2011    | Opt. Port. |
| Honduras (HND)  | 4.21%   | 2.73%   | 4.09%   | 2.73%   | 3.89%   | 1.98%   |
| Nicaragua (NIC) | 5.89%   | 2.06%   | 4.00%   | 2.06%   | 3.87%   | 1.50%   |
| Bolivia (BOL)   | 3.89%   | 1.97%   | 4.00%   | 1.97%   | 3.87%   | 1.57%   |

Notes: Shifting the actual industry portfolio to the efficient frontier by rearranging the shares of the economic activities leads to optimal industry portfolios characterized by either (a) lower risk with the same return or (b) higher return with the same risk.

Source: Annual national accounts of Latin American countries from CEPAL (2016) Statistics and Indicators database (constant 2010 prices, millions of dollars), author’s calculation.
### Table A.5 Actual vs. Optimal Portfolio for MERCOSUR Member Countries, 2011.

| Country (Code) | 2011 Opt. Portfolio | 2011 Opt. Portfolio | 2011 Opt. Portfolio |
|---------------|---------------------|---------------------|---------------------|
| Return        | 2.76% (a) 2.96% (b) | 2.98% 3.22%         | 3.67% 3.42%         |
| Risk          | 5.57% 2.69% 56.2%   | 2.06% 1.14% 2.06%   | 4.24% 2.81% 4.22%   |
| Agriculture   | 0.08 0.00 0.00      | 0.05 0.17 0.44      | 0.22 0.00 0.28      |
| Production    | 0.25 0.00 0.00      | 0.21 0.00 0.00      | 0.23 0.03 0.00      |
| Construction  | 0.05 0.00 0.00      | 0.06 0.00 0.00      | 0.07 0.00 0.00      |
| Trade         | 0.25 0.11 0.62      | 0.21 0.13 0.28      | 0.25 0.43 0.00      |
| Fin. Activities | 0.15 0.00 0.00   | 0.15 0.18 0.28      | 0.08 0.24 0.00      |
| Service Provision | 0.22 0.89 0.38 | 0.31 0.52 0.00      | 0.15 0.30 0.72      |
| **Notes:** Shifting the actual industry portfolio to the efficient frontier by rearranging the shares of the economic activities leads to optimal industry portfolios characterized by either (a) lower risk with the same return or (b) higher return with the same risk. |
| **Source:** Annual national accounts of Latin American countries from CEPAL (2016) *Statistics and Indicators* database (constant 2010 prices, millions of dollars), author’s calculation. |

### Table A.6 Actual vs. Optimal Portfolio for NON-RTA Member Countries, 2011

| Country (Code) | 2011 Opt. Portfolio | 2011 Opt. Portfolio | 2011 Opt. Portfolio |
|---------------|---------------------|---------------------|---------------------|
| Return        | 2.18% (a) 2.18% (b) | 2.58% 2.05%         | 2.92% 3.28%         |
| Risk          | 4.22% 3.21%         | 4.22% 6.06%         | 3.17% 6.00%         |
| Agriculture   | 0.09 0.24          | 0.25 0.05           | 0.33 0.00           |
| Production    | 0.18 0.04          | 0.00 0.42           | 0.00 0.00           |
| Construction  | 0.08 0.00          | 0.00 0.09           | 0.00 0.00           |
| Trade         | 0.24 0.15          | 0.32 0.22           | 0.00 0.02           |
| Fin. Activities | 0.22 0.53          | 0.40 0.08           | 0.00 0.75           |
| Service Provision | 0.20 0.04          | 0.03 0.15           | 0.67 0.23           |
| **Notes:** Shifting the actual industry portfolio to the efficient frontier by rearranging the shares of the economic activities leads to optimal industry portfolios characterized by either (a) lower risk with the same return or (b) higher return with the same risk. |
| **Source:** Annual national accounts of Latin American countries from CEPAL (2016) *Statistics and Indicators* database (constant 2010 prices, millions of dollars), author’s calculation. |