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Latin American beer production and import demand for Regional malt and malted barley*

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Abstract

The Latin American beer sector has undergone important changes over the last 25 years. The growth in beer production, consumption, and trade has been accompanied by a greater demand for malt and barley produced and traded in the region, displacing other traditional export countries of these inputs. Based on these facts, we studied the long-term relationship between this increase in beer production and the prices of imported inputs. In addition, we estimated the elaticities of demand of imported inputs of the main Latin American brewing countries. This allow as to infer about Latin America's competitive position as a supplier of its own beer inputs.

Keywords: beer inputs; import demand; cointegration; demand elasticities; regional integration.

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1 Introduction

Important changes have occurred in the Latin American beer market over last twenty-five years. These changes have occurred both from the point of view of production and consumption, with a domestic market expansion in each particular country, as well as in regional and international trade. Whereas the production and demand have stagnated in traditional regions, such as Europe, the United States (US), and Canada, non-traditional ones have had a sustained growth in these items, such as Latin America, Africa, and Asia (Swinnen, 2011). In fact, Latin America has overtaken the US and Canada joint production since 2006, which is mainly explained by the increase in beer production in Brazil and Mexico. Furthermore, Mexico has become the world's leading exporter, surpassing the main traditional beer exporters since 2010, such as the Netherlands, Belgium, and Germany (Thomé and Soares, 2015). So much so that in 2019 Mexican exports doubled those of Netherlands, the second largest exporter in the world (WTEx, 2020).

Latin America has positioned itself as one of the main beer-consuming regions. In particular, it is remarkable the case of Brazil, which together with China and the United States has become one of the main beer markets in world (Swinnen and Briski, 2017). According to the World Health Organization (WHO) consumption series, there are some common facts in the changes in alcohol consumption patterns that can be highlighted (WHO, 2018). Specifically, while the amount of total alcohol consumption is decreasing considering the last 30 years, the same is not true for beer, which shows a growing trend. This shows a propensity of consumption in the region in favor of beer, to the detriment of other beverages of habitual consumption like wine and spirits. In particular, in those countries where wine consumption was traditionally predominant, such as Argentina, Chile, and Uruguay, beer consumption has come to equal or exceed it. Similarly, in countries such as Peru, Paraguay, Bolivia, and a large majority of the countries of Central America and the Caribbean, where the consumption of spirits has historically been the predominant one, beer has taken its place over the total number of alcoholic beverages consumed (see country profiles from WHO, 2018).

This growth in beer production, which has been absorbed by a higher regional and international demand, led to an increased need for the main inputs or ingredients for beer manufacture, that is, malt and malted barley. Traditionally, inputs for beer production in Latin America had been imported from others regions. For example, barley had mainly come from Australia, US, and Canada. In the 1990's, these three countries accounted for 63% of total barley imports in Latin America on average. Although the participation of Argentinian and Uruguayan malt was important in this period, imports from other regions still accounted for more than half (68% on average), mainly from Europe, US, and Canada. However, over the last 20 years that trend has changed. Latin American countries have become the main supplier of barley in the region since 2003; this occurred a little later with malt (2012). The Argentinian and Uruguayan share in the imports of Latin American barley increased from 12% in 2000 to 95% in 2018; from 37% to 51% in malt in the same period. In this way, both countries became leader suppliers in the region.

This *verticalization* of regional production finds its support both on the theoretical and empirical literature. For example, Berlingieri et al. (2018) showed that multinationals have incentives to vertically integrate high cost shared (or more technologically important) such as malt for beer. Additionally, Alfaro et al. (2016) pointed out that product prices could determine vertical integration through a "pecuniary" channel when the benefits in terms of increased profitability due to higher product prices are higher than integrated costs. Since the average beer prices in Latin America have increased over the period (see Blecher et al., 2018), this could has been the channel that encourages the production of local inputs.

From this new production configuration characterized by a greater vertical integration at regional level, two research questions arise that will be addressed in this paper. First, if this evolution towards a greater composition of regional inputs has been beneficial for beer production in terms of the response of price inputs. That is, have input prices decreased in response to increased beer production? The answer to this question is not trivial, since the increased demand for inputs has effects that could more than offset the effect of increased supply and competitive pressure among suppliers. Second, since malt and malt barley production must compete with other high-quality productions from other regions (e.g. European Union, Canada, and Russia, among others), it is of interest to know how competitive the region is when relative prices and beer production (and therefore, the total input demand) change. To answer the first question, the long-term relationship of cointegration between beer production and input prices will be studied. For the second one, import demand systems will be estimated, differentiating them by origin (Latin American countries versus non-Latin American countries). Parameter estimates are used to compute elasticities to quantify how Latin American beer producers respond to changes in inputs prices in Latin and non-Latin American countries; as well as to know how an increase in input demand is distributed due to the growth of beer production. Ultimately, the aim is to evaluate the competitive performance of beer, malt, and barley production in Latin America, based on the quantification of price relationships and the behavior of the beer industry as demander of inputs from the same region and from other internationally competitive countries.

In the literature, there are some papers on different aspects of the beer industry in Latin American countries, but not so many on the relationship between regional beer production and regional trade of its main inputs. Mena et al. (2016) presented an interesting study on the history and evolution of the Latin American beer industry, covering in general lines, the evolution of production and trade as well as some issues related to mergers and acquisitions by multinational beer companies. Bullard (2004) provided a characterization of the institutional aspects of competition in Latin American beer markets. On the other hand, Toro-Gonzalez (2015) analyzed some market conditions of brewing industry in Latin America with special attention to the potential of micro brewing firms. In another paper (Toro-Gonzalez, 2017), he focused on the expansion of the craft beer production in the region and the potential of the market for its development. In particular, for Latin America countries, there are some works on the evolution of beer sector in each country focusing on productive aspects as well as on the evolution of the market structure. Among others, Rendón and Mejia (2005) studied the production of Mexican beer and its relationship with economic cycles of US and Mexico; de Freitas (2015) showed the economic importance of the Brazilian beer sector and the role of regulation; Trujillo-Sandoval et al. (2018) analized the evolution of economic concentration in the Ecuadorian brewery market; Casarin et al. (2019) studied the Peruvian brewing market in terms of the role of competition policy in market power; and Benítez and Tórda (2019) evaluated the effects of mergers in the Argentinian beer market. At the same time, there is a lot of recent literature on the growth and evolution of craft beer in the region (e.g. de Oliveira Dias and Falconi, 2018; Duarte Alonso et al., 2020; Toro-Gonzalez, 2015, 2018; Colino et al., 2017, among others). However, few studies have focused on the role of the production and trade of beer inputs (malt and/or barley) in the region and its relationship with the growing production of beer, so the present papers seeks to fill this gap. Among the studies that have addressed the demand for imports of beer supplies, the one by Satyanarayana et al. (1999) can be highlighted, since they include some Latin American countries that demanded imported malt, such as Brazil and Venezuela, although in a very different regional context from the one presented in our paper.

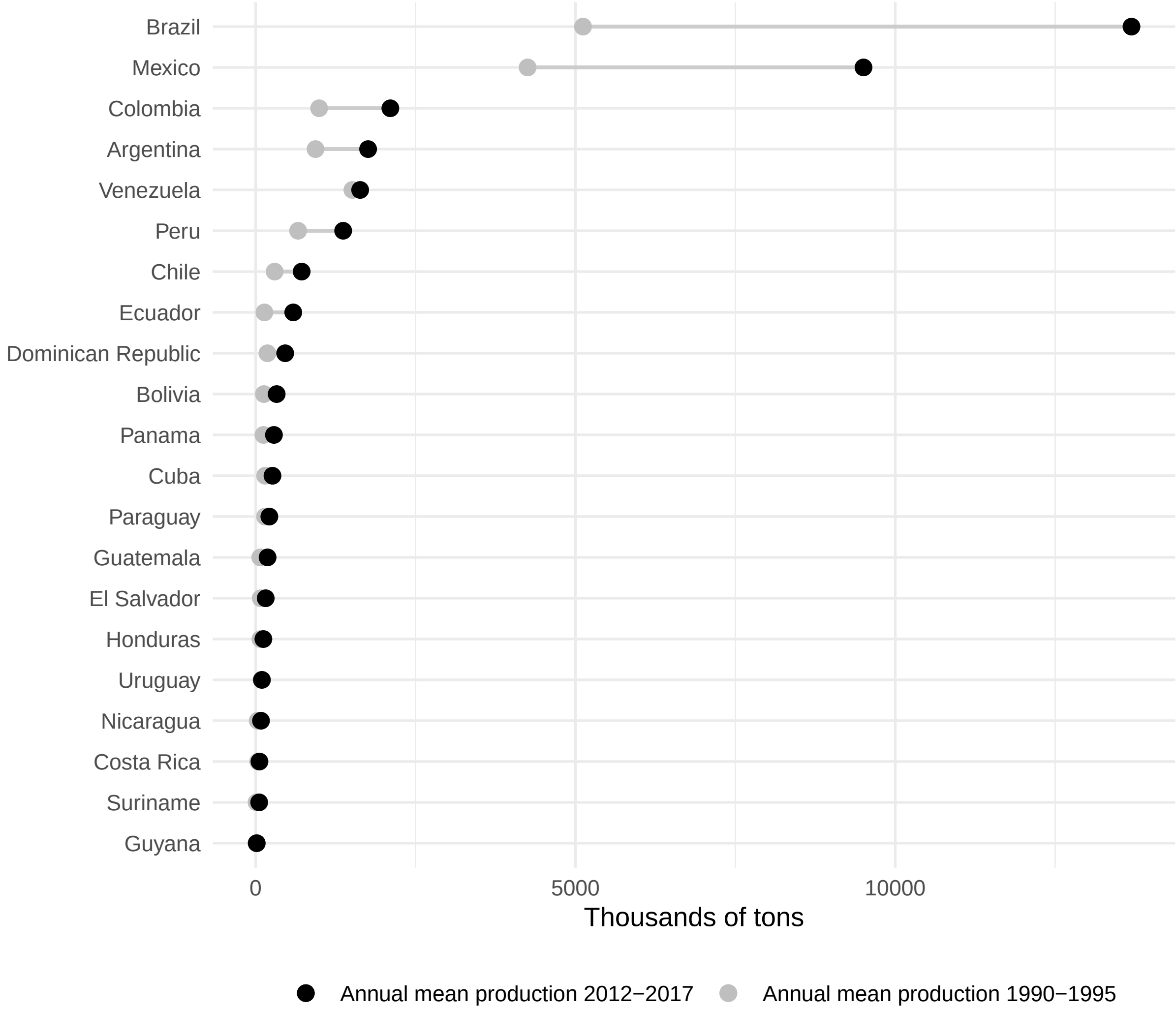
The rest of this paper is structured as follows: the following section briefly describes the evolution of beer production and the changes that have occurred in the demand for imported of malt and barley according to their origin (Latin American or not). The econometric methodologies and the data to be used are presented in Materials and methods. In Results and discussion, both the results of the cointegration model of input prices and beer production and the estimated import demand models with their respective elasticities are discussed. Some brief conclusions are presented at the end.

2 Evolution of beer production in Latin America and changes in the sources of imported inputs

Beer production in Latin America has shown a continuously increasing trend, almost tripling in the last 30 years. Figure 1 shows the growth of production for each country in the region between the average for the periods 1990-1995 and 2012-2017, ranking countries according to the produced volume. Among the countries in the region, Brazil and Mexico are the main beer producers; they experienced a growth of beer production of 167% and 124%, respectively, in the period. Together they account for 60-70% of the total beer production in Latin America. However, the production of these countries is also important worldwide, and their remarkable growth placed them in the top world ranking: Brazil stepped from the fifteenth level to the fourth level and Mexico from the eighth level to sixth level from the 1980s to the new century (Yenne, 2014).

In addition to Brazil and Mexico, the rest of the Latin American countries also experienced a growth in beer production in the period under consideration, although at different rates. Colombia and Argentina, which are ranked third and fourth in regional production, had a productive growth

Figure 1: Latin American beer production by main producers



Source: Own elaboration.

of approximately 122% and 88%, respectively. On the other hand, Venezuela, which until 2012 was ranked third in the region, only grew by 8% during the period. This is due to the precipitous drop in national production that began in 2015, which went from 2 billion liters in that year to 720 million in 2017, closing in 2019 with just 250 million[1]. As a result of the exchange control imposed by the Venezuelan government in 2016, imports of malt and barley were restricted, leading the most important brewing companies to stop their production[2]. In fact, between 1990-1995 and 2006-2011, Venezuelan beer production increased by 53%, while between 2012 and 2017, it decreased by 66%. For Peru and Chile, we can also observe a notable growth, more than doubling their beer production in the period. In turn, Ecuador, which is the next in the ranking with position eight, is the one that reveals the highest growth in the region in proportional terms, increasing its average production

[1]http://www.producto.com.ve/pro/mercados/peor-o-cerveza-nacional. Accessed: 2020-11-29

[2]https://www.bbc.com/mundo/noticias/2016/04/160429-venezuela-polar-paraliza-plantas-cerveza-divisas-escasez-ab. Accessed: 2020-11-29

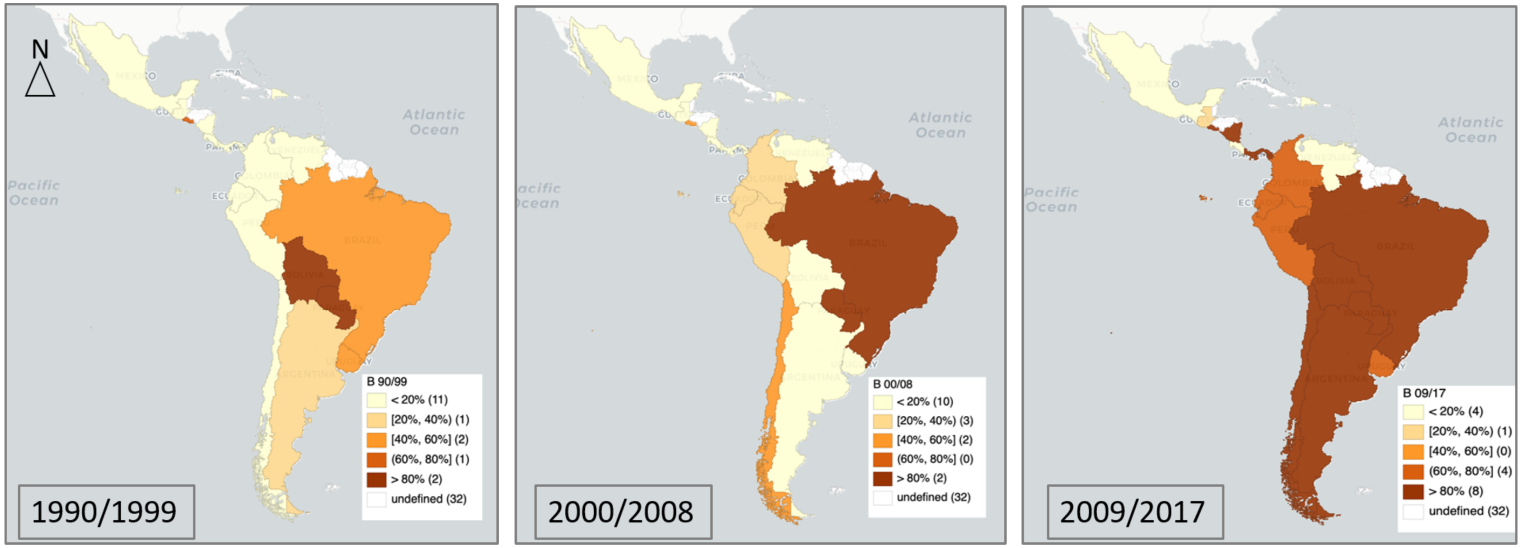
by 330% between 1990-1995 and 2012-2017. With this increase, Ecuador surpassed the Dominican Republic that previously occupied its place in the ranking and became the nation with the highest production within Central America and the Caribbean.

The rest of the Latin American countries, in despite of having a considerably lower beer production than the leaders of the region, also registered a very relevant increase in terms of production. For example, Bolivia, Guatemala, and Nicaragua show an increase in production of more than 150% in the period. Some managed to double it, such as Panama and El Salvador, while others showed slower growth (of approximately 50%), such as Uruguay, Paraguay, and Costa Rica.

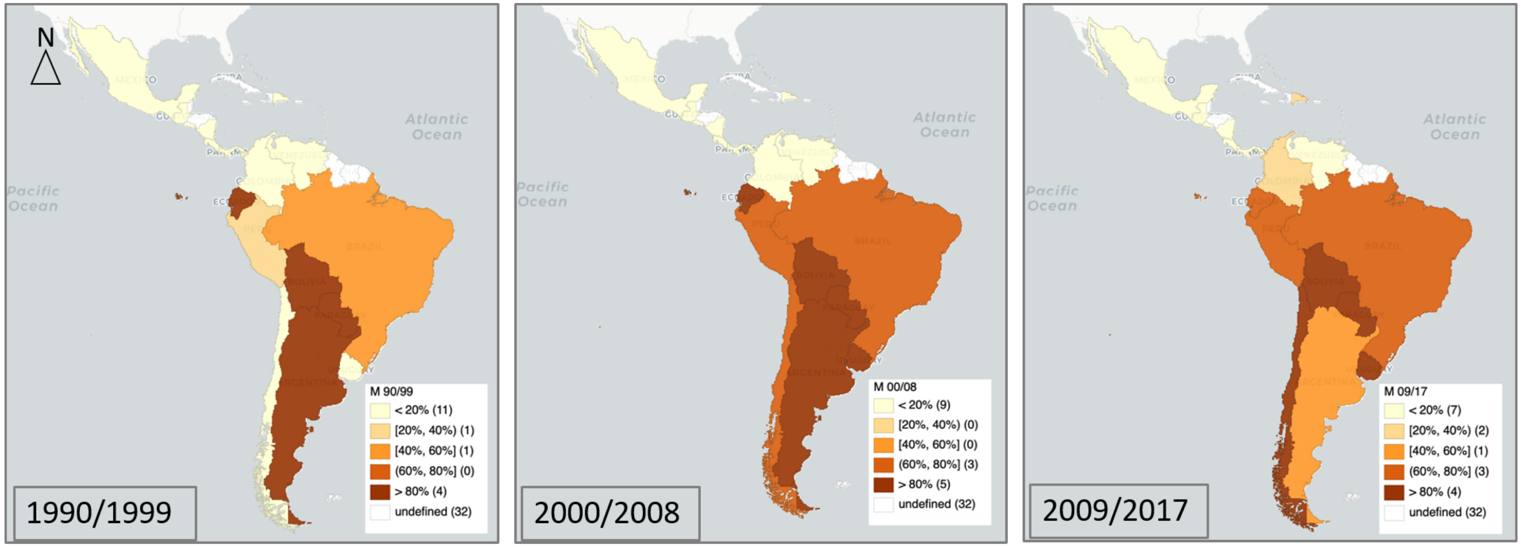
These changes in production volume happened at the time of production structure variations. Historically, beer production inputs have been demanded from others regions different from Latin America, predominantly Australia, US, and Canada as barley exporters, and European countries, US, and Canada as malt exporters. However, over the past 20 years that trend has changed. Specifically, since 2003 Latin American countries have become the main barley supplier in the region and since 2012 the same occurred with malt, with a leading role of Argentina and Uruguay as input exporters.

During the last decades, a few Latin American countries has significantly increased their barley production reaching markets usually supplied by North American, Russian, and European barley. Farmers from Argentina, Uruguay, Chile, and Mexico have changed their traditionally winter planting – made up by wheat, oat, lucerne, and spring planting, such as corn, soybeans and sunflowers – to barley production. Although these behaviors respond to the international price increase, it is related to the internal public policies that have also taken place in its regional economies. Since 1970, Argentina has sustained a positive trend in its barley production setting some years of record production. In this sense, although since 2000 Argentinian barley production has increased strongly, productive data shows that since 2004 the amount of barley grew exponentially, consolidating 2012 as a record year (MinAgri, 2016). This fact agreed with the announcement made by the current government those days referred to taxes on the export of wheat as well as other major crops. As wheat competes with barley sharing the same sowing season, this could partially explain the large increase in barley production. Usually, export taxes to major crops in Argentina encourage farmers to sow alternative crops exempted from paying taxes. Another fact that could explain the boost in Argentinian barley production is the domestic demand, for which barley production is mediated by agreed contracts where beer companies and farmers agree on quantity, quality, and delivery dates of barley crops.

Figure 2: Latin American barley and malt import participation in total imports, by countries



(a) Barley



(b) Malt

Source: Own elaboration

Figure 2 presents maps with the average evolution, in three selected periods, of the Latin American export share in the total imports of barley and malt made by each Latin American country. As it could be seen in these maps, almost all the countries in southern Latin America increase the import participation of Latin American origin of both barley and malt. On average, all these countries imported barley about 28% of the total barley imports from the region in 1990/1999, growing to 60% in 2009/2017. In particular countries, such as Chile, Peru, Colombia, and Ecuador, there is an increase in their barley imports from the Latin American region from almost zero in 1990/1999 to 75% in 2009/2017, on average.

Although the increase was smaller, Latin America malt import participation in total malt imports went from 29% to 43% between 1990/1999 and 2009/2017. In the first decade of the period covered, Ecuador, Argentina, Bolivia, and Paraguay were the main buyers of Latin American malt. More than 80% of the total malt imported by these countries had Latin American origin in the 1990s, followed by Brazil and Peru, countries where Latin American malt accounted for less than 60% and 40% of their total malt imports, respectively. At the beginning of the new millennium, with the sustained increase in barley production in southern Latin American countries, Latin American malt seems to be consolidating itself as the main beer input in several countries in the region, for example, in Uruguay, where the participation of Latin American malt amounts to more than 80 percent. Moreover, other countries such as Peru, Brazil, and Chile end up registering between 60 and 80 percent of their malt imports from Latin American countries. The last decade analyzed has as its protagonist Brazil, a country that together with Uruguay, Chile, Bolivia, and Paraguay place the participation of Latin American malt in the quartile with the highest value. On the other hand, Mexico remained throughout the period as an extra regional importer of both barley and malt.

3 Materials and methods

To learn about Latin American beer producers behavior in terms of the demand for inputs (i.e. malt and malted barley) and its association with beer production, we first sought to determine the long-term relationships that potentially exist between the prices of these production factors and output supply. This was done using cointegration techniques for panel data on these variables. In this way, we sought to know the dynamics of these variables, i.e. how they move when exogenous changes or disturbances occur in the associated markets. As mentioned above, this seeks to contrast whether the convergence toward a greater composition of regional inputs (greater demand for inputs imported from the same region) has been beneficial to beer production in terms of achieving lower input prices. Second, we rationalized the producers' import behavior using a flexible system based on a microeconomic model of allocation. Specifically, within the so-called *Differential Approach*, we adopted a general demand system that encompasses different specifications commonly used. With the econometric specification of this model, we estimated input demand elasticities, which will allow us to quantify the producers' short-term behavior in the region under prices and production changes. The methodological tools to address both approaches will be detailed in the following two subsections.

3.1 Cointegration methods for beer production and input prices

As mentioned above, the malt and malted barley used for beer production in Latin American countries come mainly from imports, so the CIF implicit prices of these inputs can be considered as the cost unit value that enters into the production decisions of beer companies. In fact, these prices are considered as *demand prices* because it can be considered that beer companies are demanding these inputs at those prices. Taking into account this feature, given the supply of these inputs, a demand increase would generate an increase in their prices, thus encouraging their production. At the same time, an increase in input supply (e.g. an increase in the Latin American malt and barley production), pushes prices down, assuming that these inputs are close substitutes for those already existing in the market (i.e. of similar quality). Then, from a standard microeconomics point of view, the net long-term effect on input prices is not clear.

But if we consider the increased Latin American malt and barley supply as a vertical integration process within the region, then, following McAfee (1999), we might expect that the final effect will be lower prices (costs) of inputs from all sources. The argument behind this result is the reaction of other input suppliers to vertical integration. Specifically, the phenomena of vertical integration consist of reducing the demand for imported inputs from other regions to give easier access to Latin American inputs, which tends to lower the prices of foreign inputs. This, in turn, induces Latin American suppliers to sell their inputs at lower prices as well, which may reduce the input cost from all origins[3]. In order to contrast such hypothesis and to know the order of such association, it is necessary to explore the empirical long-term relations between beer production and those input prices to clarify whether there is a common behavior of them through Latin American countries. In that sense, cointegration analysis is a useful tool to measure comovements among variables to know if they are potentially stablely related in the long run. This is interesting for economic purposes as it allows us to know if the variation of economic variables has a common trend, that is if variations in one of them are related with the change in the others.

For cointegration panel data analysis, unit root tests are performed for each variables at first. The Augmented Dickey Fuller (ADF) test is done following Choi (2001), as it does not require strongly balanced data, and the individual series can have gaps. After that, for testing cointegration relationships between the production of beer and the import prices of malted barley and malt, three panel data contegration test are performed: Kao (1999), Pedroni (1999), and Westerlund (2005). All of them allow including panel-specific means (fixed effects) and panel-specific time trends in

[3]The conclusion obtained from this approach is opposite to the one of the so-called *raising rival's cost theory*, which predicts an increase in the cost of inputs as a result of vertical integration (Salinger, 1988; Hart and Tirole, 1990; Ordover et al., 1990)

the cointegrating regression model.

Following Wang and Wu (2012), it is considered the time-series matrix process $(y_t, \mathbf{x}_t^{'})^{'}$ in panel data, which have correlation relationship,

$$\begin{aligned} y_{1t} &= \mathbf{x}_t^{'}\beta + \mathbf{d}_{1t}^{'}\gamma_1 + \mathbf{u}_{1t} \\ \mathbf{x}_t &= \Gamma_1\mathbf{d}_{1t} + \Gamma_2\mathbf{d}_{2t} + \epsilon_t \\ \Delta\epsilon_t &= \mathbf{u}_{2t}, \end{aligned} \tag{1}$$

where $\mathbf{d}_{1t}$ and $\mathbf{d}_{2t}$ are deterministic trend regressors. The former enters into both the cointegretion and regressors equations and the latter only in the regressor equation. A priori, the three variables are considered endogenous, which is contrasted by performing the Granger causality test. In any case, the long-term relationship will be presented by taking y_{1t} as the price of malt and $\mathbf{x}_t$ as the beer production and the price of barley. This is in line with the hypothesis to be tested: higher beer production increases the demand for inputs, encourages the production of inputs from Latin America competing with other foreign suppliers, and generates a decrease in malt costs. Since barley is an input for malt, a positive price transmission between them is expected. Furthermore, even when it would be interesting to differenciate between Latin and non-Latin American prices for the study, the data structure does not allow to do so, as prices come from import data at country level and there is too much missing information to get a complete data set for an estimation.

It is also known that if there is a long-term correlation in error structure, the OLS estimation is not efficient. For this purpose, a Dynamic Ordinary Least Squares (DOLS), a Fully Modified Ordinary Least Squares (FMOLS), and a Canonical Cointegration Regression (CCR) could be implemented as estimation methods, and the one with the best fit goodness in their estimations might be selected.

3.2 Differential approach to malt and malted barley imports

Malted barley is one of the main brew industry inputs. In the case of Latin America, most of the countries have to import malt or malted barley to meet the requirements of this activity. Import decision depends on firms behavior, and therefore the microeconomic production approach seems the most appropriate (Laitinen, 1980; Laitinen and Theil, 1978). Nonetheless, the data needed to estimate input demand functions are not available for the period and countries analyzed in the present work. Hence, like Satyanarayana et al. (1999), we modeled the import decision of malt and barley following the consumer theory approach. In fact, the second-stage procedures in the consumer and production approaches yield empirically identical demand systems and equivalent conditional elasticities (Washington and Kilmer, 2002). Therefore, accounting for this data restriction, the differences in both approaches are interpretation matters.

A wide range of models have been developed for the estimation of source differentiated import demand systems in applied agricultural economics. However, the Rotterdam (Barten, 1964; Theil, 1965) and the AIDS (Deaton and Muellbauer, 1980) models have become the most popular ones in this field. In the present study, we proposed a general demand system that encompasses the Rotterdam model and the differential version of the linear approximation of AIDS model, and hybrids of these two (Barten, 1993; Brown et al., 1994; Erdil, 2006; Lee et al., 1994). The general system is,

$$w_i d\log q_i = (d_i + \delta_1 w_i) d\log Q + \sum_j \left[e_{ij} - \delta_2 w_i(\delta_{ij} - w_i)\right] d\log p_j, \tag{2}$$

where w_i is the commodity budget share i, $d\log q_i$ and $d\log p_j$ are the logarithmic change in the imported commodity quantity i and the price of commodity j, respectively, and $d\log Q$ is the Divisia volume index, that is $d\log Q = \sum_i w_i \log q_i$. Parameters d_i and e_{ij} are

$$\begin{aligned} d_i &= \delta_1\beta_i + (1-\delta_1)\theta_i \\ e_{ij} &= \delta_2\gamma_{ij} + (1-\delta_2)\pi_{ij}, \end{aligned} \tag{3}$$

where δ_{ij} is the Kronecker delta equal to unity if $i = j$ and zero otherwise, θ_i and π_{ij} are known parameters from the Rotterdam model, and β_i and γ_{ij} are known parameters from the AIDS model. From this parameterization, (2) becomes the Rotterdam model if $\delta_1 = \delta_2 = 0$, and the differential LA-AIDS if $\delta_1 = \delta_2 = 1$. When $\delta_1 = 1$ and $\delta_2 = 0$, equation (2) becomes in the CBS model (Keller and Van Driel, 1985), whereas if $\delta_1 = 0$ and $\delta_2 = 1$ (2) becomes the NBR model (Neves, 1987). Under the general demand system, theoretical consistency requires the following constraints

$$\begin{aligned} &\text{Adding-up:} \quad \sum_i d_i = 1 - \delta_1 \ \text{ and } \ \sum_i e_{ij} = 0 \\ &\text{Homogeneity:} \quad \sum_j e_{ij} = 0 \\ &\text{Symmetry:} \quad e_{ij} = e_{ji}. \end{aligned} \tag{4}$$

The general specification not only allows choosing the appropriate model, but also, can be taken as a demand system in its own right (Brown et al., 1994). General expenditure and conditional price elasticities take the forms

$$\eta_i = (d_i + \delta_1 w_i)/w_i \quad \text{and} \quad \eta_{ij} = [e_{ij} - \delta_2 w_i(\delta_{ij} - 1)]/w_i, \tag{5}$$

respectively.

3.3 Data and estimation

For the cointegration proposal, we used barley and malt import prices and beer production taken from UN Comtrade (2020) and FAOSTAT (2020). All are yearly variables ranging from 1990 to 2017 of 17 Latin American countries. All variables were handled in logarithm. As mentioned above, prices were implicit, so when a country did not import an item during that period, we did not have the price information of that input. That is why this panel data was unbalanced, and the reason why malt and malted barley prices were not divided into Latin and non-Latin America. After a unit root analysis in these variables, a cointegration regression was estimated in panel data using FMOLS, testing some breaks in the long-term relationship and including the panel effect, selecting the appropriate model using the Akaike Information Criterion (Khodzhimatov, 2018). The estimation was performed using the `Stata 15` statistic software.

To estimate the parameters of the differential model, we proposed the following strategy. First, to highlight the competition between barley and malt imports from Latin American countries and the rest of the world, we estimated a pooled model in a panel data framework including five countries that imported malt and barley from Latin and non-Latin America for at least two consecutive years. These countries were Brazil, Chile, Colombia, Ecuador, and Peru, and yearly data from 1992 to 2018 were used to estimate this model. Second, differential models were individually estimated for Brazil and Mexico, which are the main barley and malt importers in Latin America, as well as the major beer producers. In addition, by choosing these two countries we could represent two very different profiles in terms of the origin of the trade in beer inputs: One country (Brazil) that mainly supplied Latin American supplies and another one (Mexico) that, on the contrary, depended fundamentally on non-Latin American inputs, mainly nearby countries such as US and Canada.

Monthly data from 2010 to 2019 were used for estimation of the different model specification for the demand analysis of Mexico and Brazil. Since the import values and quantities for Mexico were not available for several months, we used export data from Mexico's suppliers. For the period 2010-2020 the major malt suppliers for Brazil were Argentina, Uruguay, and European countries such as Belgium, France, and Germany. Barley was imported almost entirely from Argentina. Hence, Brazilian imports were categorized as: malt from Latin America and the rest of the world (ROW) and barley from Latin America. Regarding Mexico, malt suppliers leaders were US, Canada, and European countries, whereas US was the main barley import source. However, barley monthly data was not available for almost half of the period considered. Therefore, we considered Mexican malt imports differentiated by three origins: US, Canada, and Europe.

For the application of equation (2), w_i is approximated by $(w_{it}+w_{it-1})/2$, $d\log q_i$ by $\log(q_{it}/q_{it-1})$ and p_i by $\log(p_{it}/p_{it-1})$, where t is time indicator. Import and export values and quantities were obtained from UN Comtrade (2020). Parameters were estimated by the maximum likelihood method using `Stata 15`. The `sem` package was used for demand system estimation, since it allowed to obtain clustered standard errors in panel data model and robust standard errors for Brazil and Mexico models. Due to the adding-up condition, one system equation was excluded: barley from the ROW in the pooled model, barley from Latin America for Brazil, and malt from Europe for Mexico. In addition, lagged budget shares were used on the right-hand-side of equation (2) to avoid simultaneity (Eales and Unnevehr, 1988, 1993). For model comparison, the statistic $\mathrm{LR} = -2[\log L(\boldsymbol{\theta}^G) - \log L(\boldsymbol{\theta}^R)]$ was computed, where $\boldsymbol{\theta}^G$ and $\boldsymbol{\theta}^R$ are the estimated coefficients vectors from the general and restricted models, that is Rotterdam, AIDS, CBS, or NBR, respectively, and $\log L(\cdot)$ represents the likelihood function log value. Under the null hypothesis, LR has an asymptotic χ^2 distribution with two degrees of freedom, that is equal to the difference between the number of free parameters of the general model and each of the four restricted models.

Homogeneity and symmetry restrictions for the varied models were evaluated by the same process. Finally, compensated price and conditional expenditure elasticities were calculated from the selected models, and their standard errors were computed by the Delta method.

4 Results and discussion

4.1 Cointegration analysis

Granger casuality, the unit root, and cointegration test results are shown in Appendix A. According to the endogeneity test, the beer production and the malted barley and malt prices[4] are endogenous, since none shows some directions in the causality test at 5% level. Analyzing variable stationarity, Table A.2 shows the ADF unit root test at level and first differences, accounting for panel specific features. All test include one lag of the variable and trend, no matter whether it is in level or first difference specification. All variables are integrated of order one, which means that they are stationary at first difference, but no at level. Thus, for multivariate modeling as well as for cointegration models, it is necessary to consider this feature. According to the unit root test results, a cointegration relationship between variables of interest was tested by using three panel data cointegration test (Table A.3). Except for Pedroni one, the null hypothesis of no cointegration is rejected at 5% level. The Pedroni p-value is so closed to 5% that it is considered as rejecting null hypothesis too. Thus, we concluded from the cointegration tests that there are some long-term relationships among variables.

Therefore, using the cointegration methodology presented in subsection 3.1, a long-term relationship between barley price and beer production with malt price as dependent was estimated for Latin America in general, including a lineal and two deterministic indicators variables in the cointegration equation. These dummies were incorporated as breaks that account for changes in the whole long-term relationship of the variables. We have seen that the share of Latin American barley and malt relative to the total leading imports took place exactly after 2005 and 2011, respectively. Thereby, we included these indicator variables as they are indeed significant in the long-term relationship using the AIC criterion in model selection.

Table 1 shows the estimated coefficients of that model. The variables are related in the long run: Malt prices are positively related with the barley prices, and negatively related with beer production. However, the former is statistically significant only at 5% level whereas the latter is at 1%. Additionally, as the barley and malt prices are positively related, then the price of the former is negatively related to beer production. In other words, the cointegration relationship is characterized by a negative association between output and input prices.

These results are in line with the hypothesis, that is, with a growing regional beer production in this period, accompanied by a greater use of Latin American malt and barley; positive changes on beer production were associated with a lower unit cost of those inputs. This does not mean

[4] All variables are in logarithm.

Table 1: Parameter estimates for cointegration equation of malt price on barley price and beer production in Latin America

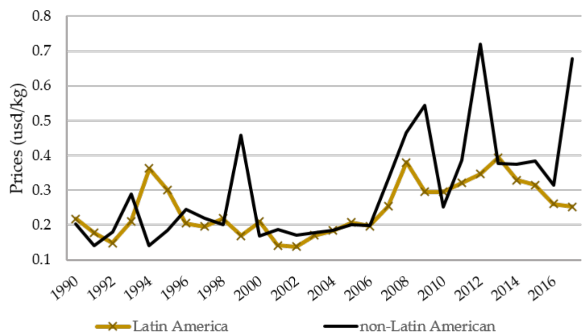
Variable	Coefficients
ln(Barley price)	0.011**
ln(Beer production)	-0.428***
linear	0.924***
After 2005	-0.027***
After 2011	2.187***
Constant	0.012
R^2	0.860
$Adj-R^2$	0.783
RMSE	0.172

Note: *** statistically significant at 1% level, ** significant at 5% level

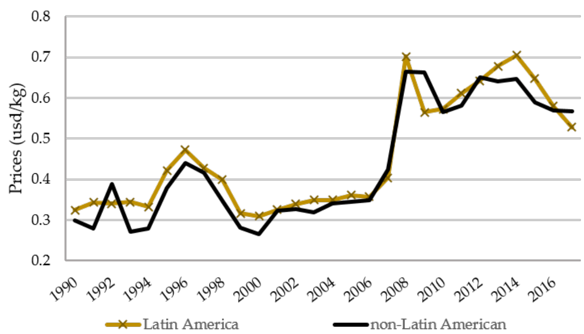
that the input prices had a decreasing trend along the period (in fact, it is increasing as shown in Figure 3) while the production increased. Actually, a long-term stable relationship between these variables was confirmed and kept even when the increases in production levels resulted in decreases in the input prices, and vice versa. Specifically, Table 1 shows that when beer production increased by 1 percent, malt prices felt by 0.43% on average over the whole period in the Latin American region.

Since the endogeneity of the three variables was statistically confirmed by causality tests, another interpretation of these results could be that beer production responds positively to cheaper inputs, which is expected from the microeconomic theory.

Figure 3: Evolution of input prices by origin



(a) Barley prices



(b) Malt prices

Source: Own elaboration.

Although we identified a growing beer production in this period with a greater use of Latin American inputs, the cointegration results do not indicate that these input prices are lower than those from other regions. In fact, as shown in Figure 3, Latin American barley prices are generally below those of non-Latin America ones, and the opposite occurs in malt prices. Therefore, this leads to the counterfactual question of whether this negative relationship between production and input prices would be kept even without the appearance of Latin American barley and malt production. This question cannot be answered with this methodology and level of data, so it represent an extension for future research.

For the specific case of Argentina, Gianello and Vicentin Masaro (2014) found a positive long-term relationship between the export prices of barley and beer. These results would not be consistent with our results for in whole Latin America, given that there was an increasing in price and beer production in the period. This may be due to the fact that Gianello and Vicentin Masaro (2014) captured the price transmission from exports to the agricultural sector, while we modeled the countries that are self-sufficient and export barley together with those that have import it mostly for beer production.

4.2 Demand analysis for imported malt and malted barley

Pooled model estimations

The different specification log-likelihoods without homogeneity and symmetry restrictions and the respective LR tests are presented in Table B.1. Results show that only the Rotterdam model is not rejected by the general system, which implies a better fit to data according to the other models. Given the model selection test results, Table B.2 shows the likelihood ratio statistics for the constraints of homogeneity and symmetry for Rotterdam model. Whereas homogeneity is not rejected, the hypothesis of homogeneity and symmetry is indeed rejected at 1% level. Although the symmetry condition for the pooled model is not fulfilled, it is imposed in the estimation to make the model consistent with economic theory.

Parameters estimated by the pooled Rotterdam model and each commodity mean shares are presented in Table 2. Single equations R^2 are 0.29, 0.22, and 0.72 for LA malt, LA barley, and ROW malt, respectively. However, the overall determination coefficient is 0.90, which implies that the whole system explains 90% of the variation in allocation[5]. The expenditure coefficient $\hat{\theta}_i$ shows the additional amount spent on commodity i when total imports increase by 1 dollar. Except for barley imported from the rest of the world, all expenditure coefficients are significantly different from zero. These coefficient magnitude implies similar preferences for malt and barley imported from Latin America and for malt imported from non-Latin American origins to fulfill beer production requirements. However, in general terms, the value of the expenditure coefficients supports the fact that for the analyzed period, imports from Latin America have a greater response

[5]Overall R^2 is computed as

$$1 - \frac{\det(\hat{\mathbf{\Psi}})}{\det(\hat{\mathbf{\Sigma}})},$$

where $\hat{\mathbf{\Psi}}$ is the estimated covariance matrix of error terms and $\hat{\mathbf{\Sigma}}$ is the estimated covariance matrix of all variables.

to increases in the total value of imports of inputs in the region. All own-price elasticities are negative and statistically significant at the 5% level, with the exception of Latin American barley. Cross price parameters reveal substitution between malt from Latin American and ROW sources and substitution between malt and barley imports from non-Latin American countries.

Table 2: Parameter estimates for pooled Rotterdam demand model

	Mean	Expenditure	Price coefficients: $\hat{\pi}_{ij}$			
	share: $\bar{s}_i$	coefficient: $\hat{\theta}_i$	LA malt	LA barley	ROW malt	ROW barley
LA malt	0.38	0.310***	-0.125**	0.003	0.125**	-0.003
		(0.111)	(0.056)	(0.013)	(0.050)	(0.034)
LA barley	0.25	0.336*		-0.113	0.059	0.051
		(0.186)		(0.089)	(0.043)	(0.043)
ROW malt	0.18	0.270***			-0.284***	0.100**
		(0.064)			(0.041)	(0.041)
ROW barley	0.19	0.084				-0.149***
		(0.103)				(0.049)

Notes: *** statistically significant at 1% level, ** significant at 5% level * significant at 10% level.

Clustered standard errors in parentheses.

Table 3 shows the import demand elasticities derived from the pooled Rotterdam model with their respective asymptotic standard errors. Except for Latin American barley, all own-price elasticities are negative and statistically significant at the 5% level. The estimated elasticities indicate that the demand for malt from Latin America and barley from the ROW sources are price inelastic, whereas the demand for malt from the ROW are price elastic. In fact, in absolute value, the own-price elasticity of Latin American malt is the lowest, which would indicate a better competitive position of the same product with respect to inputs from the rest of the world. Specifically, an increase of 10% in the price of Latin American malt would reduce on average 3.33% the quantity demanded by the Latin American countries considered in the pool, whereas if the price of malt from the ROW increases in that proportion, the quantity demanded would be reduced by 15.36% on average. In turn, barley from Latin America is totally price insensitive in statistical terms, and this also reflects a competitive advantage for Latin American barley exporters.

Cross price elasticities indicate that malt imports from Latin America are less sensitive to changes in price of ROW malt compared to the response of malt imports from the ROW to price changes in Latin American malt. The values indicate that a reduction by 10% in the price of malt imported from the ROW implies a reduction of 3.31% in the quantity of malt demanded from Latin America. On the other hand, a 10% reduction of the price of Latin American malt is associated with a 6.74% lower quantity of malt demanded from the ROW. This suggests that Latin America is more price competitive than the ROW in the Latin American malt import market. Additionally, we found a significant substitution between malt and barley from the ROW. On average, a 10% increase in the price of ROW malt (ROW Barley) would increase the quantity of ROW barley (ROW malt) demanded by Latin American countries by approximately 5%.

Finally, all expenditure elasticities are positive and statistically significant, except for ROW barley. Latin American barley and ROW malt elasticities are greater than one, implying that on average additional expenditure favors imports of these commodities. These elasticities provide a characterization of how a higher outlay on imported inputs/ingredients is distributed as the result of an increase in beer production. That is, higher expenditure on imports for beer production generates a more than proportional increase in the demand for malt from ROW and for Latin American barley, whereas the demand for Latin American malt grows less than proportionally. On the one hand, this can be explained by the fact that during the period, Latin American malt is the one with the highest average share of the total imported inputs, therefore its increase would be smaller in proportional terms. On the other hand, these results also show that there is a trend to spend more on imported barley for the country's own malt production for subsequent beer production. A greater expenditure elasticity of ROW malt could be related to issues of the quality of certain malts for the production of specific types or brands of beer, which classifies economically this input not as a *necessity* but as a *luxury* good for Latin American beer producers.

Table 3: Elasticity estimates for pooled Rotterdam model

	Expenditure elasticity	Own and cross price elasticities			
		LA malt	LA barley	ROW malt	ROW barley
LA malt	0.824***	-0.332**	0.009	0.331**	-0.007
	(0.295)	(0.149)	(0.036)	(0.134)	(0.090)
LA barley	1.350*	0.013	-0.455	0.237	0.205
	(0.748)	(0.054)	(0.358)	(0.174)	(0.174)
ROW malt	1.462***	0.674**	0.319	-1.536***	0.543**
	(0.347)	(0.273)	(0.235)	(0.223)	(0.224)
ROW barley	0.442	-0.014	0.269	0.527**	-0.782***
	(0.540)	(0.178)	(0.228)	(0.218)	(0.259)

Notes: *** statistically significant at 1% level, ** significant at 5% level * significant at 10% level

Asymptotic standard errors in parentheses.

Brazil and Mexico input demand elasticities

In this subsection, we present the demand estimations for imported inputs for the two main beer-producing countries in Latin America, that is Mexico and Brazil. We perform a separate analysis for them, according to their relevance and particularity as malt and barley demanding countries.

Likelihood ratio tests for model selection indicate that Rotterdam and AIDS models show a better fit to data for Brazil and Mexico, respectively, than the other specifications (Table B.3 in Appendix B). In addition, homogeneity and symmetry constraints are not rejected for these two models at 1% significance level (Table B.4 in Appendix B). Therefore, we choose the Rotterdam specification for Brazil and the AIDS specification for Mexico to model the import behavior.

Table 4 shows parameter estimates for the Brazilian demand model and average shares of each commodity. The overall coefficient of determination is 0.88, which implies that the variability in allocation between these commodities is 88% explained by the whole system. For the period 2010-2020, malt and barley comes mainly from Latin American sources, which accounts for 87% of the total imports on average. All expenditure coefficients are positive and significantly different from zero. Own-price coefficients are negative, but the ROW equation is statistically significant only for malt. On the other hand, cross-price coefficients shows that both barley and malt from Latin America compete with malt from the ROW in the Brazilian market.

Table 4: Parameter estimates for the Brazilian Rotterdam demand model

	Mean	Expenditure	Price coefficients: $\hat{\pi}_{ij}$		
	share: $\bar{s}_i$	Coefficient: $\hat{\theta}_i$	LA malt	ROW malt	LA barley
LA malt	0.65	0.639***	-0.139	0.299***	-0.161
		(0.045)	(0.162)	(0.077)	(0.149)
ROW malt	0.13	0.112***		-0.490***	0.191***
		(0.026)		(0.075)	(0.068)
LA barley	0.22	0.249***			-0.031
		(0.042)			(0.157)

Notes: ***statistically significant at 1% level, ** significant at 5% level *significant at 10% level.
Robust standard errors in parentheses.

Brazilian import demand elasticities are reported in Table 5. From the own-price elasticities, we could infer that the Brazilian demands for imported malt and malted barley from Latin America are inelastic and not statistically different to zero. These results are consistent with the ones of the pooled model, in the sense that the demand response for Latin American inputs is invariant under own-price variations, which indicates an advantageous position for its exporters. On the contrary, the Brazilian demand for malt imported from the ROW is very elastic. Specifically, a change of 10% in the price of malt from the ROW countries produces an opposite change in the quantity demanded of 37.1% as response. Additionally, this demand is elastic with respect to Latin American input prices (cross-price elasticities). However, demands for Latin American malt and barley are inelastic with respect to the prices of foreign malt. Despite this, these cross-price elasticities show that the demand for Latin American inputs would only be sensitive to the prices of malt from its competitors from the ROW. As in the pooled case, we found that Latin American inputs are more difficult to substitute (due to price changes) than those from the ROW; in the case of Brazil, the gap between substitution possibilities is much greater.

Expenditure elasticities are similar and do not differ significantly from one, which implies that additional expenditure allocations would be equally shared among the three commodities, with a slight preferences toward the ones from Latin American sources.

Table 5: Elasticity estimates for the Brazilian Rotterdam demand model

	Expenditure	Own and cross price elasticities		
	elasticity	LA malt	ROW malt	LA barley
LA malt	0.978***	-0.213	0.458***	-0.246
	(0.069)	(0.248)	(0.117)	(0.227)
ROW malt	0.848***	2.266***	-3.713***	1.447***
	(0.193)	(0.579)	(0.566)	(0.514)
LA barley	1.159***	-0.747	0.890***	-0.143
	(0.195)	(0.692)	(0.316)	(0.728)

Notes: ***statistically significant at 1% level, ** significant at 5% level *significant at 10% level. Asymptotic standard errors in parentheses.

These results found for the Brazilian market are close to those obtained by Satyanarayana et al. (1999). Although they considered a different period, the elasticities reported are in line with those found here. First, the expenditure elasticities for European and South American malt do not differ significantly from one. Second, while average shares were 0.46 and 0.37 for European and South American sources, respectively, own-price elasticities were -1.04 for the former and -0.44 for the latter. This shows not only the growing importance of Latin American countries in the Brazilian market, but also the increase in competitiveness achieved by them, as can be seen from the comparison of elasticities.

The estimated parameters and mean shares of each commodity for the Mexican AIDS model are presented in Table 6. For the Mexican model, the overall determination coefficient is 0.63, which indicates that the system explains 63% of the variation in allocation. The interpretation of the AIDS model coefficients is not as straightforward as in the Rotterdam model case. Expenditure coefficients indicate the change in the share of the commodity i for a unit proportional change in total imports or expenditure. The sign of these coefficients shows that both the US malt and Canadian malt are characterized as *necessities* whereas the European malt could be perceived as *luxury*.

On the other hand, the price coefficient indicates the change in share of commodity i for a unit proportional change in the price of commodity j. US and Canadian prices have negative effects on share of the US malt, whereas European price has direct effects. Price coefficients in the equation for Canada are not significantly different from zero, except for the US price. The European share increases with the rise of the US price whereas it decreases with the increase of its own price. These relationships become clearer when analyzing the elasticity estimates.

Table 6: Parameter estimates for the Mexican AIDS model

	Mean	Expenditure	Price coefficients: $\hat{\gamma}_{ij}$		
	share: $\bar{s}_i$	coefficient: $\hat{\beta}_i$	US malt	Canada malt	EUR malt
US malt	0.75	-0.286***	-0.163*	-0.118***	0.282***
		(0.072)	(0.094)	(0.039)	(0.102)
Canada malt	0.17	-0.088***		0.040	0.078
		(0.028)		(0.036)	(0.051)
EUR malt	0.08	0.374***			-0.360***
		(0.076)			(0.125)

Notes: *** statistically significant at 1% level, ** significant at 5% level, * significant at 10% level.
Robust standard errors in parentheses.

Table 7 shows the estimated demand elasticities for the Mexican market. Note in own-price elasticities that the Mexican demand for malt from the US and Canada is inelastic with respect to their own prices: on average, a 10% increase in malt prices implies a 4.6% and 5.9% reduction in the quantities demanded, respectively. Nevertheless, the European malt import demand is very elastic, showing that a 10% increase in its price reduces by half the quantity demanded. In addition, in the values of cross-price elasticities, there is a high substitution in the demand for European malt when the prices of its competitors (Canada and US) change. In turn, there are no cross-price effects between US and Canada. Finally, as it was deduced from demand coefficients, expenditure elasticities indicate that a higher expenditure on malt imports produces a greater proportional weight on the demand for European malt, which is expected given its low market share in relation to US and Canada.

When comparing with Brazil, we found similarities in the malt demand behavior of Mexico with respect to the price of its North American neighbors and with Latin American exporters. At the same time, in the same way that Brazil has a very elastic demand for malt imported from the ROW (in which Belgium is the main exporter), Mexico has a very elastic demand for malt of European origin. This would suggest a greater competitiveness (through prices) of the malt from American countries compared to the malt from European ones. The main difference between the demands from Mexico and Brazil is that the Latin American input demand elasticity converges to zero whereas the US and Canada input demand is is greater than zero even when it is inelastic. This shows a greater market positioning of Latin American countries in the Brazilian beer input (i.e. malt and malted barley) markets than the one that North American countries have in the Mexican malt market.

Finally, these results found for both countries reflect the role of multilateral free trade agreements, that is, NAFTA for Mexico and Mercosur for Brazil, as pointed out by Mena et al. (2016)

in terms of the consolidation of national companies. Each one has competitive advantages in terms of input availability from the main producer countries from the American continent: Canada and US for Mexico, and Argentina and Uruguay for Brazil. At the same time, these malt and barley exporters have a strong competitive position reflected in high market shares, low own-price elasticities, and high cross-price elasticities with respect to other competitors.

Table 7: Elasticity Estimates for the Mexican AIDS model

	Expenditure	Own and cross price elasticities		
	elasticity	US malt	Canada malt	Europe malt
US malt	0.6206***	-0.4624***	0.0144	0.4480***
	(0.0954)	(0.1245)	(0.0519)	(0.1347)
Canada malt	0.4881***	0.0635	-0.5936***	0.5301*
	(0.1636)	(0.2284)	(0.2111)	(0.2968)
Europe malt	6.0237***	4.5401***	1.2209*	-5.7610***
	(1.0262)	(1.3656)	(0.6835)	(1.6800)

Notes: *** statistically significant at 1% level, ** significant at 5% level * significant at 10% level.

Asymptotic standard errors in parentheses.

5 Conclusions

In the present paper, we addressed the phenomenon of the growing demand for Latin American malt and barley within the same region. We interpreted this phenomenon as a process of vertical integration of the region, and from this hypothesis, the general aim of this research was to characterize the phenomenon in terms of its effects on the brewing industry competitiveness as well as on the main beer input producers/exporters. In particular, we studied the relationship between input prices and beer production and then analyzed the behavior of Latin American countries as importers of malt and barley from both the same and other regions, such as Europe and North America (excluding Mexico).

This greater participation of Latin American input exporters accompanied a continuous growth on beer production into a greater trade liberalization context, a multilateral trade agreement signing, a growing firm internationalization and more concentrated markets from numerous mergers and acquisitions that took place in most nations in the region.

To carry out this study, we used different techniques and econometric models. First, we used panel data cointegration techniques to quantify the long-term relationship between input prices and beer production. Second, we estimated import demand systems to obtain imported malt and barley demand elasticities. We used last methodology for grouped data, to model the main Latin American countries that demand malt and barley in the region, as well as study in a disaggregated way Brazil and Mexico, the two main producers in the region.

From the cointegration approach, we found a negative long-term relationship between input prices and beer production. Therefore, we can conclude that this period with growing beer production, characterized with a vertical integration process within the region, is consistent with the achievement of lower input prices.

Based on the malt and malted barley import demand elasticities, a strong competitive positioning of Latin American exporters is observed, supported by increasing shares in importing markets, lower (and in some cases, zero) own-price elasticities, and lower sensitivity with respect to the competing prices from countries in other regions. On the other hand, expenditure elasticities allow Latin American inputs to be classified in microeconomic terms as necessary goods for beer production, whereas those from the rest of the world are classified as luxury goods.

Finally, it is clear the role that free trade agreements play on the main beer producers of the region, that is, Mexico and Brazil, which based on NAFTA and Mercosur, achieved a bloc integration with a strong competitive positioning of malt and barley exporters.

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Appendices

A Tests for cointegration analysis

Table A.1: Granger-causality test

H_0			z-bar estadistic	p-value
Beer production	does not cause	Barley price	2.217	0.027
Beer production	does not cause	Malt price	8.038	0.000
Barley price	does not cause	Beer production	8.979	0.000
Barley price	does not cause	Malt price	5.796	0.000
Malt price	does not cause	Beer production	3.049	0.002
Malt price	does not cause	Barley price	8.038	0.000

Notes: Granger – causality test, accounting panel data features

Table A.2: Augmented Dickey Fuller unit root tests

Variables	Level	First difference
Beer production	1.98	-13.13
	[0.976]	[0.000]
Barley price	0.054	-7.44
	[0.522]	[0.000]
Malt price	1.001	-5.504
	[0.842]	[0.000]
# Panels	17	

Notes: data in brackets are p-values

Table A.3: Cointegration tests

	Statistic	p-value
Kao*	2.5103	0.006
Pedroni*	1.5757	0.0575
Westerlund**	-2.2191	0.0132
# Panles	17	

Notes* are ADF statistics, ** are variance ratio

B Tests for demand analysis

Table B.1: Test results for model selection

	Log likelihoods[a]	LR[b]
General	640.9608	
Rotterdam	638.4166	5.0884
AIDS	623.8189	34.2836
CBS	628.5854	24.7508
NBR	632.2119	17.4977

[a] Log likelihoods from unrestricted models, that is, without homogeneity and symmetry.

[b] Table value for χ_2^2 at $\alpha = 0.01$ is 9.21.

Table B.2: Test results for Rotterdam model constraints

	Log likelihoods	LR[a]
Unrestricted	638.4166	
Homogeneity	634.3502	8.1327(3)
Homogeneity and symmetry	624.4001	28.0330(6)

[a] Degrees of freedom in parentheses.

Table values for χ_3^2 and χ_6^2 at $\alpha = 0.01$ are 11.34 and 16.81, respectively.

Table B.3: Test results for model selection

	Brazil		Mexico	
	Log likelihoods[a]	LR[b]	Log likelihoods[a]	LR[b]
General model	1206.6641		1299.4450	
Rotterdam	1205.5415	2.2452	1292.8442	13.2016
AIDS	1202.5699	8.1884	1298.9575	0.9750
CBS	1203.7450	5.8382	1297.5022	3.8856
NBR	1205.1728	2.9826	1294.0875	10.7150

[a] Log likelihoods from unrestricted models, that is, without homogeneity and symmetry.

[b] Table value for χ_2^2 at $\alpha = 0.01$ is 9.21.

Table B.4: Test results for model constraints

	Brazil Rotterdam		Mexico AIDS	
	Log likelihoods	LR[a]	Log likelihoods	LR[a]
Unrestricted	1205.5415		1298.9575	
Homogeneity	1204.3056	2.4718(2)	1295.1225	7.6700(2)
Homogeneity and symmetry	1202.7631	5.5568(3)	1294.4805	8.9540(3)

[a] Degrees of freedom in parentheses. Table values for χ^2_2 and χ^2_3 at $\alpha = 0.01$ are 9.21 and 11.34, respectively.