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Available online at www.centmapress.org

Int. J. Food System Dynamics 15 (2), 2024, 185-203

DOI: https://dx.doi.org/10.18461/ijfsd.v15i2.J6

INTERNATIONAL JOURNAL ON FOOD SYSTEM DYNAMICS

Latin American beer production and import demand for regional malt and malted barley

Rodrigo García Arancibia[1,2], Jimena Vicentin Masaro[2,3], and Mariano Coronel[2]

[1]Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Colectora Ruta Nacional N° 168, Km 0, S3000 Santa Fe de la Vera Cruz, Argentina.
[2]Instituto de Economía Aplicada Litoral (IECAL-FCE), Universidad Nacional del Litoral, Moreno 2557 (3000), Santa Fe, Argentina.
[3]Fundación INAI, Avda. Corrientes 127. CP: C1043AAB. Buenos Aires, Argentina.
r.garcia.arancibia@gmail.com; mcoronel@fce.unl.edu.ar; jime.v.masaro@gmail.com.ar

Received July 2023, accepted February 2024, available online April 2024

ABSTRACT

Over the last 25 years, the Latin American beer sector has undergone important changes. 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 elasticities of demand of imported inputs of the main Latin American brewing countries. This allows us 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.*

1 Introduction

Significant transformations have transpired within the Latin American beer market over the last twenty-five years. These alterations manifest from dual standpoints encompassing both production and consumption. There has been a notable expansion in the domestic market within individual countries and an upsurge in regional and international trade. Notably, while production and demand have plateaued in conventional regions like Europe, the United States (US), and Canada, non-traditional regions such as Latin America, Africa, and Asia have experienced consistent growth in these domains (Swinnen, 2011).

Remarkably, Latin America has surpassed the joint production of the US and Canada since 2006, largely propelled by heightened beer production in Brazil and Mexico. Additionally, Mexico has ascended to the pinnacle as the world's foremost beer exporter, outstripping major traditional beer-exporting nations since 2010, including the Netherlands, Belgium, and Germany (Thomé and Soares, 2015). In 2019, Mexican exports doubled those of the Netherlands, which held the position of the world's second-largest exporter (WTEx, 2020).

On the other hand, Latin America has emerged as a primary hub for beer consumption. Notably, Brazil stands out alongside China and the US as one of the leading beer markets globally (Swinnen and Briski, 2017).

The surge in beer production, spurred by heightened regional and global demand, amplified the necessity for primary inputs in beer crafting—namely, malt and malted barley. Historically, Latin America relied on imports for these brewing essentials from other regions. For instance, barley primarily arrived from Australia, the US, and Canada. In the 1990s, these three countries accounted for an average of 63% of total barley imports into Latin America. Although Argentinian and Uruguayan malt had notable participation during this era, imports from other regions still constituted more than half (averaging 68%), primarily originating from Europe, the US, and Canada.

However, a significant shift has occurred over the last two decades. Since 2003, Latin American countries have emerged as the primary barley suppliers in the region; a trend that materialized slightly later for malt, around 2012. The proportion of Argentinian and Uruguayan contributions to Latin American barley imports surged from 12% in 2000 to a striking 95% in 2018. Similarly, in the malt domain, their share rose from 37% to 51% within the same timeframe. Consequently, both nations ascended as leading suppliers within the region.

Within this new production framework marked by heightened regional vertical integration, this paper addresses two research inquiries. Firstly, it explores whether this shift towards a greater reliance on regional inputs has positively impacted beer production by affecting input prices. Specifically, has the increased production led to decreased input prices? Answering this question is not straightforward as the augmented input demand might counteract the effect of increased supply and competitive pressures among suppliers. Secondly, considering that malt and malt barley production competes with high-quality productions from other regions like the European Union, Canada, and Russia, 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 tackle the first query, the paper examines the long-term co-integration relationship between beer production and input prices. For the second, it estimates import demand systems, distinguishing between the origins of imports (Latin American countries versus non-Latin American countries). Parameter estimates are used to compute elasticities, quantifying how Latin American beer producers react to input price changes in Latin and non-Latin American countries, as well as understanding how the increased input demand is distributed due to beer production growth. Ultimately, the paper aims to evaluate the competitive performance of beer, malt, and barley production in Latin America. This evaluation is based on quantifying price relationships and analyzing the behavior of the beer industry as it seeks inputs from within the region and from other highly competitive international markets.

The subsequent sections of this paper are structured as follows: the upcoming section provides a brief review of the related literature. Then, the next section gives an overview of beer production evolution and the shifts in demand for imported malt and barley based on their origins (Latin American or otherwise). The subsequent section outlines the econometric methodologies and data to be employed, detailed under 'Materials and Methods.' The 'Results and Discussion' section covers the outcomes from the co-integration model linking input prices and beer production, alongside discussions on estimated import demand models and their corresponding elasticities. Finally, the paper concludes with concise remarks.

2 A brief review of the literature

The vertical integration of regional production is supported by theoretical and empirical literature. Berlingieri et al. (2018) demonstrated multinational corporations' inclination to vertically integrate for high-cost shared products, such as malt for brewing, due to their technological significance. Moreover, Alfaro et al. (2016) highlighted how product prices can drive vertical integration, where increased profitability from higher prices outweighs integrated costs. The escalating average beer prices across Latin America, as noted by Blecher et al. (2018), may have stimulated local input production. According to De Simone et al. (2021), the use of local or autochthonous cultivars of cereals is one of the most explored strategies for the regionalization of beer production. In fact, using local/regional components has various advantages, including building ties with regions, increasing the added value of the final products (e.g., Atallah et al. 2021, Melewar and Skinner, 2020), and lowering supply costs and environmental impacts (e.g., Gatrell et al., 2018; Ness, 2018, Cappozzi et al. 2021; among others). Thus, as long as it is feasible to do so by providing, at least in part, with local inputs, there are many incentives for the regionalization of the beer production.

While existing literature covers diverse aspects of the Latin American beer industry, there is a gap regarding the connection between regional beer production and the trade of its primary inputs. Mena et al. (2016) provided a comprehensive study on the history and evolution of the industry, encompassing production, trade developments, and aspects of multinational beer companies' mergers and acquisitions. Bullard (2004) focused on characterizing competition within Latin American beer markets. In contrast, Toro-Gonzalez (2015) scrutinized brewing industry market conditions, emphasizing the potential of microbrewing firms. Other studies examined the evolution of the beer sector in individual Latin American nations, emphasizing production aspects and market structure changes. For instance, Rendón and Mejia (2005) studied Mexican beer production and its relation to economic cycles in the US and Mexico; de Freitas (2015) emphasized the economic significance of Brazil's beer sector and regulatory roles. Meanwhile, recent literature extensively covers the growth of craft beer in the region (e.g., Garavaglia and Swinnen, 2017; Colino et al., 2017; Toro-Gonzalez, 2017, 2018; Oliveira Dias et al., 2017; Duarte Alonso et al., 2020), yet scant attention has been given to the role of beer input production and trade (malt and/or barley) in correlation with increasing beer production. This paper aims to address this gap.

Regarding studies on beer supply import demand, Satyanarayana et al. (1999) included select Latin American countries like Brazil and Venezuela, although within a different regional context from the focus of our paper.

3 Evolution of beer production in Latin America and changes in the imported inputs origins

Beer production in Latin America has exhibited a consistent upward trajectory, nearly tripling over the past three decades. Figure 1 illustrates the production growth for each country in the region, comparing averages between the periods of 1990-1995 and 2012-2017, ranking nations by production volume. Within the region, Brazil and Mexico emerge as the primary beer producers, witnessing production spikes of 167% and 124%, respectively, during this period. Together, they contribute to 60-70% of the total beer production in Latin America. Notably, their production holds global significance as well, propelling Brazil from the fifteenth to the fourth position and Mexico from the eighth to the sixth position into the world rankings between the 1980s and the new millennium (Yenne, 2014).

Apart from Brazil and Mexico, other Latin American countries have also undergone varied growth rates in beer production during the considered period. Colombia and Argentina, securing the third and fourth positions in regional production, experienced production hikes of approximately 122% and 88% respectively. Conversely, Venezuela, previously holding the third position until 2012, encountered a meager 8% growth during this period. This decline stemmed from a significant national production plummet starting in 2015, dropping from 2 billion liters to 720 million in 2017 and further down to a mere 250[1] million in 2019. The Venezuelan government's imposition of exchange control in 2016 restricted malt and barley imports, prompting major brewing companies to halt production[2]. Notably, between 1990-1995 and 2006-2011, Venezuelan beer production ascended by 53%, but from 2012 to 2017, it plummeted by 66%.

Peru and Chile also exhibited substantial growth, more than doubling their beer production within the period. Meanwhile, Ecuador, which is at eighth position, showcased the most significant proportional growth in the region, boosting its average production by 330% between 1990-1995 and 2012-2017. This surge enabled Ecuador to surpass the Dominican Republic, previously occupying its position, becoming the highest beer producer within Central America and the Caribbean.

Even with considerably lower beer production compared to the regional leaders, other Latin American countries demonstrated noteworthy production increases. Bolivia, Guatemala, and Nicaragua showed production hikes exceeding 150% during the period. Some managed to double their production, such as Panama and El Salvador, while others displayed slower growth rates, around 50%, like Uruguay, Paraguay, and Costa Rica.

[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

During these shifts in production volume, significant alterations occurred within the production structure. Historically, beer production relied on inputs sourced predominantly from regions outside Latin America, mainly Australia, the US, and Canada as exporters of barley, and European countries, the US, and Canada as malt exporters. However, this trend underwent a notable change over the last two decades. Specifically, starting from 2003, Latin American nations emerged as the primary barley suppliers in the region. A similar transition transpired with malt since 2012, where Argentina and Uruguay played pivotal roles as exporters of these inputs.

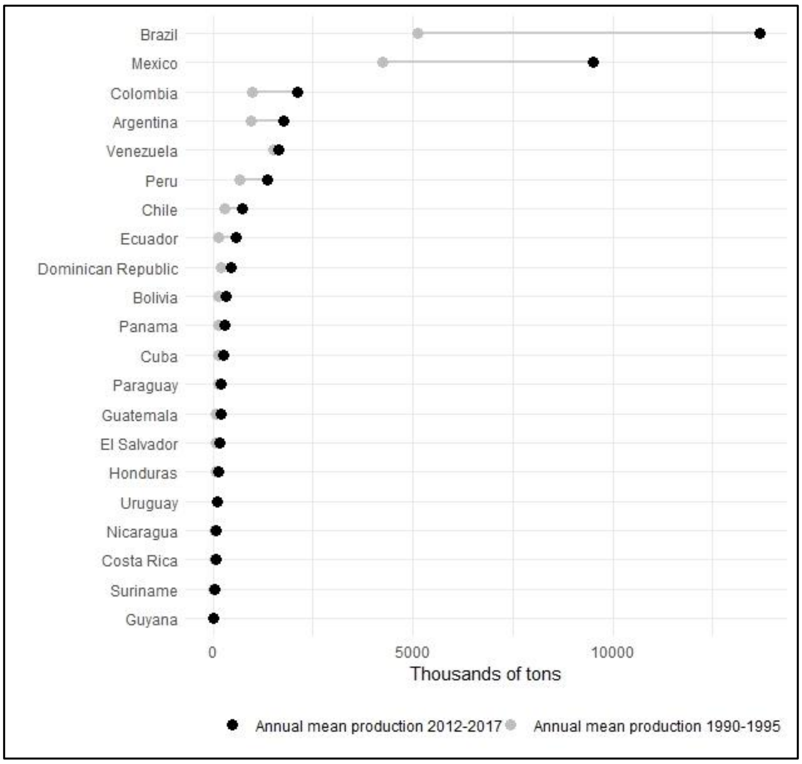
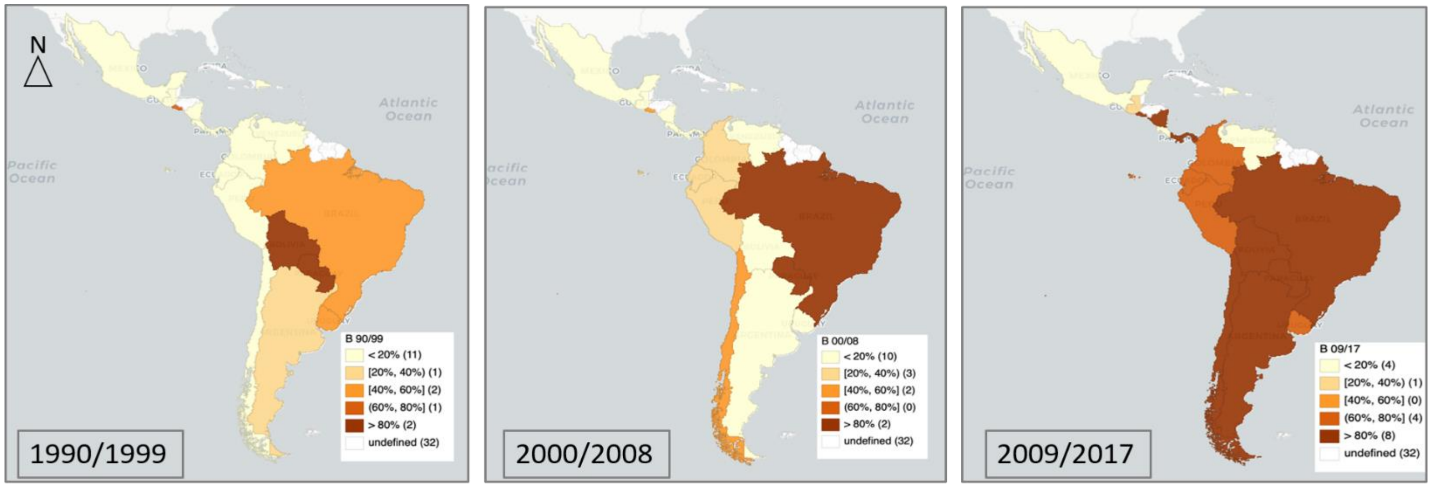


Figure 1. Latin American beer production by main producers
Source: Own elaboration.

During the last decades, a few Latin American countries have 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 presents maps with the average evolution of the Latin American export share in the total imports of barley and malt made by each Latin American country, in three selected periods. 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. Particularly 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.

a) Barley



b) Malt

Figure 2. Latin American barley and malt participation in total imports, by countries
Source: Own elaboration (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 by using cointegration techniques for panel data on these variables. 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 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 Co-integration 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 affect the production decisions of beer companies. In fact, these prices are considered as demand prices because it is supposed that beer companies are demanding these inputs at those prices. Considering 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 is that the reaction of other input suppliers to vertical integration. Specifically, the phenomena of vertical integration consist of reducing the imported inputs from other regions demand 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]. 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 co-movements among variables to know if they are potentially stably related in the long run. This is interesting for economic purposes as it allows 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 variable 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 cointegration 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 the cointegrating regression model.

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

$$
\begin{aligned}
\boldsymbol{y}_{1t} &= \boldsymbol{x}_t'\beta + \boldsymbol{d}_{1t}'\gamma_1 + \boldsymbol{u}_{1t} \\
\boldsymbol{x}_t &= \Gamma_1 \boldsymbol{d}_{1t} + \Gamma_2 \boldsymbol{d}_{2t} + \varepsilon_t \qquad (1) \\
\Delta\varepsilon_t &= \boldsymbol{u}_{2t},
\end{aligned}
$$

where $\boldsymbol{d}_{1t}$ and $\boldsymbol{d}_{2t}$ are deterministic trend regressors. The former goes into both the cointegration 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 $\boldsymbol{x}_t$ as the beer production and the price of barley. This is in line with the hypothesis to be tested: higher

[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).

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 differentiate between Latin and non-Latin American prices, 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 need to import malt or malted barley to meet the requirements of this activity. Import decision depends on firm's 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,

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

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:

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

The general specification brings 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,

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

respectively.

3.3 Data and estimation

For the cointegration proposal, we used barley and malt import prices and beer production taken from United Nations (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 to Latin American 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 supplier 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 allows 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 $LR = -2[\log L(\boldsymbol{\theta}^G) - \log L(\boldsymbol{\theta}^R)]$ 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 $\log L(.)$ 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 tests include a lag of the variable and trend, no matter whether it is level or first difference specification. All variables are integrated of order one, which means that they are stationary at first difference, but no

[4] All variables are in logarithm.

at level. According to the unit root test results, a cointegration relationship between variables of interest was tested by using three panel data cointegration tests (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.

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 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 associated to beer production. In other words, the cointegration relationship is characterized by a negative association between output and input prices.

Table 1.

Parameter estimates for co-integration equation of malt price on barley price and beer production in Latin America

Variable	Coefficients
Logarithm of Barley price	0.011*
Logarithm of Beer Production	-0.428***
linear	0.924***
After 2005	-0.027***
After 2011	2.187***
Constant	0.012
R-squared	0.86
Adjusted R-squared	0.783
RMSE	0.172

Note: *** Statistically significant at 1% level; **significant at 5%.

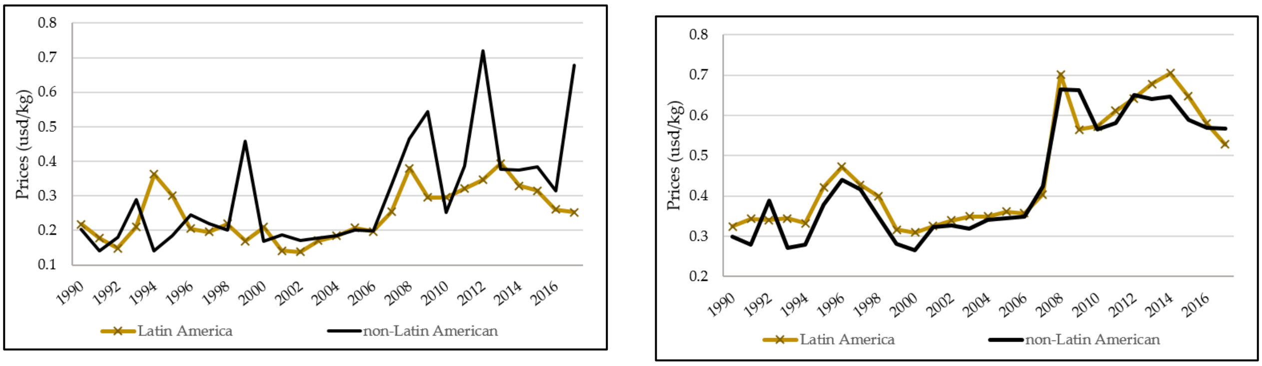
These results are in line with the hypothesis of a growing regional beer production in this period, accompanied by a greater use of Latin American malt and barley; positive changes on beer production were associated with a lower unit cost of those inputs. This does not mean that the input prices had a decreasing trend along the period (in fact, it is increasing as shown in Figure 3) while the production increased. 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.

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 represents 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 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.



(a) Barley prices (b) Malt prices

Figure 3. Evolution of input prices by origin
Source: Own elaboration.

4.2 Demand analysis for imports of malt and malted barley

4.21 Pooled model estimations

The different specification log-likelihoods without homogeneity and symmetry restrictions and the respective *LR* tests are presented in Table B.1 in Appendix B. Results show that only the Rotterdam model is not rejected by the general system, which implies a better fit in comparison to the other models. Given the model selection test results, Table B.2[5] shows the likelihood ratio statistics for the constraints of homogeneity and symmetry for Rotterdam model. Whereas homogeneity is not rejected, the homogeneity and symmetry hypothesis 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[6]. 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. The magnitude of the coefficient implies similar preferences for malt and barley imports from Latin America and for malt imports from non-Latin American origins to fulfill beer production requirements. However, in general terms, the value of the expenditure coefficients supports the notion that imports from Latin America have a greater response to increases in the total value of imports of inputs in the region for the analyzed period. All own-price elasticities are negative and statistically significant at the 5% level, except Latin American barley. Cross price parameters reveal substitution between malt from Latin American and ROW origin and substitution between malt and barley imports from non-Latin American countries.

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 malt demand from Latin America origin and barley from the ROW origin are price inelastic, whereas the malt demand from the ROW are price elastic. In fact, in absolute value, the own-price elasticity of Latin

[5] In Appendix B

[6] Overall R^2 is computed as $1-\frac{\det(\hat{\Psi})}{\det(\hat{\Sigma})}$, where $\hat{\Psi}$ is the estimated covariance matrix of error terms and $\hat{\Sigma}$ is the estimated covariance matrix of all variables.

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 reflects a competitive advantage for Latin American barley exporters.

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.

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. So, 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 origin. 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%.

Table 3.
Elasticity estimates for pooled Rotterdam model

	Expenditure	Own and cross price elasticities			
	elasticity	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.

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 malt demand from ROW origin 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, 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 to 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.

4.22 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.

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.

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 are mainly imported from Latin American origin, 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.

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.

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.

On the contrary, the Brazilian demand for malt imported from the ROW is very elastic (Table 5). 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 related to the prices of foreign malt. Despite, these cross-price elasticities show that Latin American inputs demand 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 preference toward the ones from Latin American origin.

These results are closed to those obtained by Satyanarayana et al. (1999). Although they considered a different period, the elasticities reported are in line with those found here to Brazilian market. 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 origin, 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 elasticities' comparisons.

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, i.e. the system explains 63% of the variation in allocation. The AIDS model coefficients interpretation 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*.

Table 6.
Parameter estimates for the Mexican AIDS model

	Mean share: $\bar{s}_i$	Expenditure coefficient: $\hat{\beta}_i$	Price coefficients: $\hat{\gamma}_{ij}$ 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.

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 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 for European malt demand 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. 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 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, the 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's competitiveness as well as on the main beer input producers and exporters. This greater participation of Latin American input exporters accompanied a continuous growth in beer production into a greater trade liberalization context, a multilateral trade agreement signing, growing firm internationalization, and more concentrated markets from numerous mergers and acquisitions that took place in most nations in the region. In such a context, the gains of input regionalization for the Latin American beer sector are far being trivial, and elucidating such a phenomenon could contribute to the decision-making of the entire beer chain in the region to strengthen its international competitiveness.

The general aim of the paper was addressed through two specific research inquiries: Firstly, we investigated whether the greater reliance on regional ingredients impacted Latin American beer production positively through lower input prices. Secondly, we inquired about the region's level of competitiveness when it comes to changes in relative prices and total input demand, given that the local production of malt and malted barley in Latin America must compete with high-quality productions from other countries (o regions) such as the European Union and North America (excluding Mexico). In this way, we studied the relationship between input prices and beer production and then analyzed the behavior of Latin American countries as malt and barley importers and from both the same and foreign regions.

To carry out this study, we used different econometric models and methods. To tackle the first research question, panel data co-integration techniques were used to quantify the long-term relationship between input prices and beer production. To address the second issue, we estimated import demand systems to obtain malt and barley import demand elasticities. We used the 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 during this period with growing beer production, characterized with a vertical integration process within the region, is consistent with the achievement of lower input prices. This process could result in a competitive advantage and greater flexibility for the brewing industry in the region to respond to profound changes in the patterns and preferences of beer consumers.

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. In addition, from import demand system estimations, 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.

The results we obtained seek to be useful for the Latin American brewing sector, considering primary production (malted barley), intermediate production (malt), and the production of the final good (beer). From our empirical findings, we were able to confirm that the increase in regional beer production, accompanied by a regional integration process via greater participation of regional brewing ingredients, was beneficial through a reduction in costs via lower input prices. At the same time, such integration seems to be sustainable in terms of maintaining the positioning of local input producers compared to exporters from other regions.

Acknowledgments

Our research was made possible through support by the Agencia Nacional de Promoción a la Investigación, el Desarrollo Tecnológico y la Innovación (Ministerio de Ciencia, Tecnología e Innovación, Argentina), under Grant PICT 2018-04377. We thank Ana Laura Chara for her work as a research assistant, contributing to the data collection and maps.

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Appendices

Appendix 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
# Panels	17	

Notes* are ADF statistics, ** are variance ratio.

Appendix 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 likelihood from unrestricted models, that is, without homogeneity and symmetry. [b] Table value for χ^2_2 at α = 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] Degree of freedom in parentheses. Table values for χ_3^2 and χ_6^2 at α = 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 likelihood from unrestricted models, that is, without homogeneity and symmetry. [b] Table value for χ_2^2 at α = 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]