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Competition in the International Niobium Market: An Econometric Study

Abstract

Niobium is a highly strategic mineral, in which Brazil holds almost all of the world's reserves followed by Canada. Niobium has an important role in steel alloys for the aerospace industry and future potential for the industry's superconductors. The present paper investigates the prevailing market power in niobium at the country level by referencing the residual demand approach advanced by Goldberg and Knetter (1999). The empirical evidence for the American destination market indicates a significant market power for Brazil. However, despite Brazil's strong dominance in the supply of ferroniobium in comparison to Canada, it has moderate market power, which may suggest that other metals can have a relevant role in composing high performance alloys in terms of complementarity or substitution relationships.

JEL-Codes: F140, L130, L610.

Keywords: Niobium, residual demand, market power.

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1. Introduction

The intensity of competition in national markets for exports is a recurring topic in the literature, and departures from the law of one price appear to be often induced by exchange rate fluctuations [see Feenstra (1989), Hooper and Mann (1989) and Feenstra et al. (1996) for relevant discussions on exchange rates pass-through].

The assessment of market power in selected industries benefited from developments in the industrial organization literature that devised methodologies for identifying the intensity of competition when marginal costs are not observed [see Bresnahan (1989) and Baker and Bresnahan (1992) for overviews of the so-called New Empirical Industrial Organization-NEIO]. It is possible to highlight two salient research strategies that pertain to the way firms and industries respond to changes in the elasticity of demand or in the marginal cost. The latter conceptual experiment considers residual demand estimations that attempt to identify a firm’s ability to profitably implement cost pass-through following firm-specific cost shocks. This methodology is advanced by Baker and Bresnahan (1988) in the context of firm-level analysis.

Goldberg and Knetter (1999) adapt the aforementioned framework to address the intensity of competition in international markets by focusing on exports to a selected destination market with the analysis carried out at the country level. Specifically, the authors estimate elasticities of residual demands by taking as references the U.S. linerboard paper and the German beer export industries and obtain estimates that appear to be plausible given the available information on market shares and number of competitors. Analogous applications were undertaken by Bragança (2005) in the case of main exporters of coffee to the U.S. destination market and by Coronel et al. (2010) in terms of main exports of soymeal to the European Union market. In both cases, despite Brazil’s large market share, its indicated market power is particularly low. In Bragança’s

(2005) study, such a result is likely to reflect important product differentiation accruing from Colombian competition.

The present paper investigates the market power in the U.S. and EU destination markets for exports of ferro-niobium, an important intermediate product used for producing high performance steel alloys. The paper contributes to the literature in at least two aspects as follows:

a) Niobium has an important role in steel alloys for the aerospace industry and future potential for the industry's superconductors. Although there are more descriptive studies reporting the main supply and demand characteristics of the niobium sector [see Laverick (1988). Campanário (1991) and Cunningham (2000)], there is a gap in the literature in terms of quantitative economic efforts. Moreover, the substantial dominance of Brazil in the world production motivates market power assessments;

b) The bulk of the NEIO literature ignores issues pertaining to non-stationarities. Exceptions, in terms of a dynamic specification, include Steen and Salvanes (1999) and Zeidan and Resende (2009) situated within the strand of literature that considers changes in the elasticity of demand for identifying market power. In contrast, previous works did not consider non-stationarity and cointegration issues in the residual demand estimation. In fact, Goldberg and Knetter (1999) advanced in methodological terms by adapting firm-level residual demand estimation to national markets. However, a shortcoming of the empirical application was the very short annual time series that were used and thus hindered addressing the aforementioned econometric issues.

The paper is organized as follows. The second section discusses the conceptual aspects involved in residual demand estimation at the country level. The third section provides basic background on the niobium sector and discusses the construction of the database. The fourth section presents and discusses the econometric results. The fifth section provides some final comments.

2. Residual Demand Estimation

2.1- Basic concepts

Bresnahan (1989) and Baker and Bresnahan (1992) highlight residual demand estimation as an appealing approach for assessing market power in oligopolistic markets. The basic conceptual experiment attempts to isolate situations where firm-specific cost shocks are profitably transmitted to prices, and thus, the firm can actually exercise market power. Baker and Bresnahan (1988) laid the foundation for the identification of firm-level market power through residual demand estimation when marginal costs are not observed. The approach is parsimonious, as it does not require the estimation of the various cross price elasticities of demand, and the analysis relies on the residual demand elasticity, which indicates the demand perceived by a specific firm after taking into account all supply and demand adjustments. The prevalence of market power is associated with a steep residual demand, and thus, the residual demand elasticity and its possible interpretation in terms of the mark-up have an important role.

Goldberg and Knetter (1999) adapt the approach in the context of aggregate data related to exporters from different source countries that compete in the same destination market. Their approach assumes perfect substitution between products within each source market. However, goods produced by different exporting countries may not be perfect substitutes.

The approach advanced by Goldberg and Knetter (1999) can be summarized as follows. Consider a group of exporters selling to a particular foreign destination market, focusing on the estimation of the residual demand a given exporting country (denoted by k). Let p^{ex} and Q^{ex} indicate price and exported quantity, respectively, by a given source country

A for the destination country. Moreover, let $p^1, \dots p^n$ indicate prices for the n competing exporting countries, and Z represent a vector of demand shifters at the destination market, where prices are expressed in terms of the destination market currency. The set of demand equations will be given by:

$$p^{ex} = D^{ex}(Q^{ex}, p^1, \dots \dots \dots \dots .., p^n, Z) \quad (1)$$

$$p^k = D^k(Q^k, p^j, p^{ex}, Z) \text{ where } j = 1, \dots \dots ., n \text{ and } j \neq k \quad (2)$$

To obtain the residual demand for the reference country, it is necessary to consider the optimizing behaviour of the remaining competitors. Thus, from the first-order conditions follows the equality between perceived marginal revenue and marginal cost. However, as firm-level data are lacking, such as in Baker and Bresnahan (1988), it is possible to consider market shares weights (s_i) and obtain aggregate conditions by summation. Thus, one can obtain the following supply relations in the context of aggregate data and interpret parameters as industry averages.

$$p^{ex} = e.MC^{ex\prime}Q^{ex}.D_1^{ex}.\ \theta\ .\ \phi \quad (3)$$

where e indicates the exchange rate in the destination market currency; the weighted marginal cost in the source country is given by $MC^{ex} = \Sigma_I\ s_i\ MC_i^{ex}$, and in a similar vein, Q^{ex} denotes the (weighted) aggregate quantity for the export group; D_1^{ex} represents the partial derivative of the demand function with respect to the first argument, whereas θ and ϕ respectively denotes the (weighted) aggregate quantity for the export group; D_1^{ex} represents the partial derivative of the demand function with respect to the first argument, whereas θ and ϕ respectively refer to (weighted) aggregate capturing the competitive behaviour among exporters within the source country and competition between source country and other exporters.

Similarly, the following expression represents the supply relations of the competitors:

$$p^k = e.MC^k Q^{ex}.D_1^k.\ \theta^k \quad for \quad k = 1,...,n \quad (4)$$

Expression (3) condenses the set of n-1 supply relationships for the exporting rivals of the reference country. The simultaneous solution of demand equations given by (2) and the supply relationships given by (3) expresses the prices of the competitors as a function of costs, demand shifters of the n products and the quantity Q^{ex} exported by the reference country. Letting Z denote the set of demand shifters, W^N the union of all firm-specific demand shifters (except those pertaining to the reference source country) and ς^N the union of all conduct parameters, it will follow that:

$$p^k = p^{k*}(Q^{ex}, W^N, Z, \varsigma^N), \ \ k = 1, \ldots \ldots, n \qquad (5)$$

As emphasized by the authors, expression (5) considers a set of n-1 partial reduced forms for the competitors of the reference country. Thus, a final step involves the substitution of equation 5 into equation 1, and after eliminating redundancies, one can obtain the expression for the residual demand curve of the reference country:

$$p^{ex} = D^{ex}(Q^{ex}, p^{1*}(.), \ldots \ldots ., p^{n*}(.), Z) = D^{res\ ex}(Q^{ex}, W^N, Z, \varsigma^N) \qquad (6)$$

This expression comprises three classes of observables: the quantity produced by the exporter (the reference source country), demand shifters and other firm cost shifters

The estimation of such a class of models will clearly require the consideration of instrumental variables methods given the endogeneity of the variable Q^{ex} accruing from the simultaneity between Q^{ex} and p^{ex}. The intuition for the econometric identification of the residual demand relates to detecting the ability of profitably implementing cost pass-through following exporter-specific cost shifts. In the empirical application by Goldberg and Knetter (1999), the sole exporter-specific cost shifter was provided by its exchange rate. In the empirical application later undertaken in the present paper, we will be able to consider a broader set of instruments.

2.2 - Empirical model and interpretation

The estimation of the residual demands and the related elasticities constitutes the approach considered in the present paper for assessing market power. Goldberg and Knetter (1999) adapted the firm-level approach advanced by Baker and Bresnahan (1988) to a country-level analysis to assess the intensity of the competition in different destination markets of firms located in different source markets [German beer and U.S. linerboard paper]. As emphasized by the authors, the identification of the residual demand elasticity relies on exchange rate shocks that rotate the supply relation of the source-country export group relative to competitors located in other countries, as in their application, exchange rate is the sole country-specific cost shifter. The adaptation from a firm-level to a country-level analysis necessarily involves considering average effects given the aggregation. In fact, a generic supply relation will comprise one component that captures the competitive behaviour among the exporters within the source country and another component that reflects the competitive interaction between source country firms and foreign producers. In the empirical application of the present paper, we therefore have a sharper empirical application, as we will consider the intensity of competition of the two main exporters in niobium to the U.S. market where Brazil is highly dominant relative to Canada, the second largest exporter. Moreover, the competition within source markets is very limited, as in Brazil, one firm (CBMM) dominates the supply relative to the second acting firm (Anglo American), whereas a single producer (Niobec) operates in Canada.[1]

The interpretation of the residual demand elasticity as properly portraying the intensity of competition relies on its association with the theoretical mark-up as given by the Lerner index L = $\frac{p^{ex} - MC^{ex}}{p^{ex}}$. As contended by Baker and Bresnahan (1988) and Goldberg and

[1] See section 3 for additional background on the sector.

Knetter (1999), there are some salient cases where the residual demand elasticity has an exact correspondence with the theoretical Lerner index. In fact, in the cases of consistent conjecture equilibrium, perfect competition and Stackelberg leadership with a competitive fringe allow such a clear-cut interpretation for the residual demand elasticity. Our present application, in terms of the niobium market, is associated with a homogeneous product with a dominant producer, and thus, the residual demand elasticity is an appealing indicator for the intensity of competition.

In the present paper, we consider the estimation of a system of residual demands for niobium from Brazil and Canada as directed towards the U.S. destination market. We consider a log-log functional form that in generic terms would lead to the following expression for a particular residual demand, where ε stands for a stochastic disturbance:

$$\ln p_{mt}^{ex} = \lambda_m + \eta_m Q_{mt}^{ex} + \alpha_m^{'} \ln Z_{mt} + \beta_m^{'} W_{mt}^{N} + \varepsilon_{mt} \qquad (7)$$

It is worth reinforcing that the conceptual experiment considered by residual demand estimation aims at isolating in the data situations where firm-specific (or country-specific) cost shocks can be transmitted to prices. This requires some form of instrumental variable estimation where firm-specific cost shocks must be instrumented for. Previous studies such as Baker and Bresnahan (1988), Yang (2001) and Ozawa (2005) implement the residual demand approach for firm-level studies, and yet Goldberg and Knetter (1999), Bragança (2005) and Coronel et al. (2010) did not explore the non-stationarity of the data or advance a flexible dynamic specification. In fact, the NEIO literature is essentially static, with exceptions provided by Aiginger et al. (1999), Steen and Salvanes (1999) and Zeidan and Resende (2009). However, the identification of market power may be associated with the rotation of the demand, whereas in the present case, we consider a flexible specification for the residual demand. To proceed with a dynamic empirical model in an error correction framework, it is crucial under non-stationarities to check for the prevalence of cointegration among the relevant variables of the model. The more usual approach advanced by Johansen (1988) requires that all the relevant series are integrated of first order - I(1). In many applications, and in the present case in particular, it is not uncommon to face both I(0) and I(1) series. Thus, to legitimate an error correction representation, the cointegration of the system will be verified in terms of the so-called bounds approach advanced by Pesaran et al. (2001). Once the nature of the non-stationarity of the individual series is assessed by unit root tests, the approach begins with the specification of a conditional error correction model. In contrast, with a conventional specification, it substitutes the error correction term given by the lagged residual from the cointegrating regression with lagged variables in level. This approach allows mixed orders of integration I(d) as long as d < 2. Still keeping a logarithmic specification, one would have for a representative source country:

$$\Delta \ln p_{mt}^{ex} = \delta_m + \sum_{i=1}^{n_1} \gamma_m \, \Delta \ln p_{mt-i}^{ex} + \sum_{i=1}^{n_2} \eta_{mi} \Delta \ln Q_{mt-i}^{ex} + \sum_{i-1}^{n_3} \alpha_m \ln Z_{mt} + \sum_{i=1}^{n_4} \beta_{mi} W_{mt}^{N} + \theta_1 \ln p_{m,t-1}^{ex} + \theta_2 \ln Q_{m,t-1}^{ex} + \theta_3 \ln Z_{m,t-1} + \theta_4 \ln W_{m,t-1}^{N} + \varepsilon_t \qquad (8)$$

A long-run relationship among the variables will require cointegration using an F test to detect the joint significance of the coefficients for lagged variables in levels (the θ coefficients). In the previous expression, one would need to test the null hypothesis of $\theta_1 = \theta_2 = \theta_3 = \theta_4 = 0$ that should be rejected to claim cointegration. This presentation assumes single demand and cost shifters, but of course, a more general specification is possible. It is also worth mentioning that one can potentially allow distinct lag structures for the different variables. The corresponding non-standard critical values for these tests in terms of the relevant lower and upper bounds are tabulated by the authors.

As we shall see later in the application, the evidence suggests the prevalence of cointegration among the variables and thus legitimates the consideration of an error correction model for the residual demand for each source country. Next, the specification of the relevant empirical model requires the use of the lagged residual in level obtained from the cointegrating regression in levels. In section 3.2, we outline the variables of our empirical model.

3. Brazilian niobium industry

3.1- Basic background

Niobium (Nb) is a chemical element with a high melting point that is corrosion resistant and exhibits superconductivity properties at low temperatures. Those characteristics, among others, confer important industrial applications mainly in special steels [see Laverick (1988)]. Ferro-niobium is an iron niobium alloy used to add niobium to steel to obtain greater mechanical resistance, lighter weight and reduced cost. The necessary amount of niobium to induce significant enhancements in mechanical properties is minimal. The so-called high-strength low-alloy steel (HSLA) typically has an addition of 400 g of niobium per ton of steel [see Socorro (2001)]. These steel alloys are used, for example, in oil and gas pipelines, in platforms for oil exploration in deep waters, in the shipping industry and in the building sector. Moreover, these alloys have important applications in the manufacturing of truck and car frames and wheels.

Another important application for niobium is in the production of superalloys (upon vacuum graded-VG niobium) used in materials that can be subjected to long periods in oxidating and corrosive atmosphere at temperatures above 650°C. These superalloys are used, for example, in combustion equipment, nuclear reactor cores, rocket parts and jet engine components.

Finally, it is worth mentioning the use of niobium in stainless steel manufacturing. The incorporation of niobium assures better performance at high temperatures and contributes to neutralizing the effect of carbon and nitrogen, thus providing greater durability. Table 1 illustrates main applications of niobium.

INSERT TABLE 1 AROUND HERE

The table also indicates the major firms in operation, dominated by the Brazilian company Companhia Brasileira de Metalurgia e Mineração (CBMM). Other firms include a multinational company with headquarters in England (Anglo American) that also operates a mine in Brazil and IAMGOLD/Niobec with extraction in Canada.[2]

Brazil possesses the largest niobium reserves in the world with 98.43%, followed by Canada (1.11%) and Australia (0.46%) and is also the largest producer of niobium in the world with more than 95% of the world's exports [3]. In fact, the major part of the Brazilian niobium production is directed to foreign markets. Among the destination markets for Brazilian niobium in 2011, one can highlight: Netherlands (30%), China (21%), Singapore (15%), United States (14%) and Japan (9%)[4]. In that same year, less than 10% of the total production of standard ferro-niobium alloy (66% of niobium content and 30% of iron) was directed to the domestic market. [5]

It is reasonable to say that the potential for applications of niobium has not yet been fulfilled, and despite the large supply potential and strong market dominance by a few firms in a few countries, the relevance of substitute products cannot be underestimated. In fact, vanadium, molybdenum, manganese, titanium and tantalum can be used as imperfect substitutes in some alloys, although the substitutions imply efficiency losses and increased costs [6]. In the steel industry, titanium and vanadium can be used to produce HSLA; however, ferro-vanadium alloys require twice as much content as ferro-niobium alloys[7].

[2] More recently in 2014, IAMGOLD decided to concentrate its operation in the gold segment and sold the northern Quebec mine (Niobec) to an investor group led by Magris Resources Inc.
[3] According to data from DNPM in 2010
[4] Source: Departamento Nacional de Produção Mineral (DNPM) and Instituto Brasileiro de Mineração (IBRAM)
[5] Source: DNPM
6 See Mineral Commodities Summaries - United States Geological Survey (USGS)
[7] Mineral Commodities Summaries - USGS

Finally, tantalum can also substitute niobium in the manufacturing of superalloys used in the aircraft industry for the manufacturing of special turbines and alloys that are resistant to corrosion and high temperatures. However, such metal has higher prices and high density.

In the next sub-section, we outline the data sources and definitions of the variables used in the estimated system for country-level residual demands for ferro-niobium.

3.2- Data construction

The data set was constructed using different sources. Table 2 describes the variables taking as reference the log-log specification that will be later implemented, and Table 3 provides summary statistics for the untransformed variables.

INSERT TABLES 2 AND 3 AROUND HERE

The different indexes used were put in terms of a common base period, and the basic categories, as in any NEIO study, include prices, quantities, demand shifters and cost shifters. The construction of the database aimed at matching as closely as possible disaggregated information in connection to the niobium, although in some cases, some series are more aggregated. In the present application, exports from Brazil and Canada were considered in terms of two destination markets, namely, the U.S. and the European Union (EU) in terms of its main entrance market represented by the Netherlands.

4. Empirical Results

4.1 - Unit root tests

The results are presented in Tables A1 and A2 in the appendix. A necessary first step in the empirical analysis relates to the assessment of the degree of integration of the involved series. We consider a more cautious approach by contemplating the possibility of structural breaks, as significant demand shifts associated with China have taken place over the years and Figure 1 is suggestive.

INSERT FIGURE 1 AROUND HERE

. The evidence mostly favours the non-rejection of the null hypothesis of a unit root; however, one can observe series that can be classified as I(0). We consider unit root tests that potentially allow for endogenous structural breaks as advanced by Saikkonen and Lütkepohl-SL (2002) and Lanne et al. (2002). In fact, the reliance on these more general unit root tests can be motivated by the low power of such tests under structural breaks as contended by Perron (1989). The SL test conceives a non-linear function for the change of the variable level that is added to the deterministic term of the data generating process for the variable of interest. Such additional term is considered in alternative specifications: (a) as a dummy variable with a simple change date (shift dummy), (b) based on an exponential function specification (exponential shift), and (c) as a rational function on the lag operator applied to a dummy variable for change (rational shift).[8] Even with the consideration of different functional forms' specifications, the evidence supports the prevalence of variables with different degrees of integration, with both I(0) and I(1) series. This result has consequences in terms of the cointegration test procedure, as the usual approach advanced by Johansen (1988) would require that all series in level were I(1).

INSERT TABLES A1 AND A2 AROUND HERE

4.2 – Cointegration tests

The evidence from the unit roots indicating the coexistence of both I(1) and I(0) series leads to the aforementioned procedure for testing cointegration that was advanced by

[8] Gadelha (2011) provides additional discussion on these tests in the context of a distinct application.

Pesaran et al. (2001) in their ARDL bounds approach. It is worth mentioning that the requirement that the dependent variables are I(1), as referring to pnb^{br}, is satisfied. The essence of the test, as outlined in connection to expression (8), is to implement an F test for joint significance of the coefficients of the lagged variables in level given by pnb_{t-1}^{br}, qnb_{t-1}^{br}, e_{t-1}^{can}, pva_{t-1} and pta_{t-1} for the residual demand equation for Brazil.

The joint tests were considered for model specifications with a maximum of 6 lags. The optimal lag selection relied on the Akaike information criterion (AIC). [9] The models incorporated unrestricted intercept and trend. The evidence for the joint Wald tests suggest that the rejection of the null hypothesis favours the prevalence of cointegration among the variables and therefore dissipates concerns on the possibility of spurious regressions. In fact, for the final selected model, the test statistic with F = 4.588 was significant at the level of 5%.[10] Thus, we can gain additional confidence on the estimated residual demands for Brazil in the two destination markets as presented and discussed in the next sub-section.

4.3 – Residual demand estimation results

The logic of the residual demand estimation involves the identification of situations where there are incentives for cost pass-through following specific shocks, and the ability to identify such situations indicates the prevalence of market power and is summarized by the residual demand elasticity. The oligopolistic feature of the interaction between competitors would suggest an endogeneity issue that must be addressed using a method of instrumental variables. In the particular applications of the present article, we consider a two-stage least squares (2SLS) estimator. All the estimations were implemented in the software Stata 12.0. The results for the U.S. destination market are presented in Table 4.

INSERT TABLE 4 AROUND HERE

[9] See Akaike (1974).
[10] We have used the ARDL routine in the R platform.

We have experimented with a lag structure of variables considered upon a maximum order of 3. The main criteria for model selection emphasized the validity of the chosen instruments and the significance of the coefficients. Under such logic, the most parsimonious specification was selected.

It is worth mentioning that the aerospace industry has an important role in the demand for ferro-niobium alloys. However, the related series for industrial production in that sector (available from the Federal Reserve) could not be considered in the cointegration test by Pesaran et al. (2001), as the evidence indicated that it was I(2) even in the context of more flexible unit roots that allowed for structural breaks. Other tested variables were the industrial production of iron ore alloy and the prices of molybdenum and titanium. However, either no statistical significance or invalid instruments emerged from those attempts, and thus, they were not included in the final specification of the residual demand model.

The inspection of the results reported in Table 4 first requires the consideration of the usual Sargan test for validity of the instruments to assess the orthogonality between the residuals of the estimated model and the selected instruments. One cannot reject the null hypothesis of orthogonality, and thus, the instruments appear satisfactory. In the present application, we have 3 excluded instruments for 1 endogenous variable to be instrumented, and therefore, one can also interpret the test as an over-identification test.

The individual significance of the estimated coefficients is generally satisfactory, and the expected signs were observed. Furthermore, other specifications that incorporated variables such as average real wages and industrial energy price in Canada were also considered. Nonetheless, the overall results displayed robustness, and the coefficients of those particular variables were not statistically significant. Moreover, the inclusion of such variables would require shortening the time span of the analysis, and therefore they are not included in the final specification.

Upon looking at specific results, initially it is worth highlighting the significant coefficients pertaining to the time trend and to a dummy variable for structural break (DSB)[11]. The positive significant effect reflects the strong demand growth of China. In fact, important shifts in the demand from China appear to have impacted the international market for niobium, as it has experienced an intensive growth from 2007, when average annual imports represented 5.5 tons, to 2015, when it reached 15 tons.[12]. Figure 1 is suggestive The interpretations of the estimated coefficients in a residual demand model are not always straightforward, with the exception of the main parameter of interest represented by the residual demand elasticity [see Baker and Bresnahan (1988)]. Nevertheless, it is worth mentioning the significant coefficients associated with the cost shifter of the competitor [$e^{can/usa}$(-3)] and with the demand shifters [pta(-1) and pva(-2)].[13] The negative sign of the exchange rate is intuitive, as the appreciation of the local currency would raise the cost of the competitor in the destination market and thus allow Brazilian exporters to raise prices. However, in the case of the price of vanadium, the coefficient is marginally significant, whereas as for the price of tantalum, a significant effect emerges. The mixed signs of the effects of these two related prices may suggest that those minerals have relevant roles (in terms of complementarity of substitution) in high performance alloys.

Finally, the main coefficient of interest is the elasticity of the residual demand, which under reasonable assumptions can be interpreted as the Lerner index. The evidence indicates a significant market power by Brazil in the U.S. destination market, taking into

[11] Assumes value 1 for periods within 2007-2009 and 0 otherwise.
[12] See also http://www.metal.citic.com/iwcm/UserFiles/img/zlk/03_30zn/d7.pdf, for additional details, accessed 28/09/2017

[13] A detailed analysis of the dynamic effect of exchange rates cannot be accomplished in the present analysis. However, the lagged effect is suggestive in connection to complex dynamics that can emerge and possible J patterns associated with export revenue responses to exchange rates. Bahmani-Oskooee et al. (2014) finds evidence of such patterns for different exporting sectors in Brazil, including the mineral sector that includes ferro-niobium. A general survey on J curve can be found in Bahmani-Oskooee and Ratha (2004).

account restrictions imposed by the main competitor (Canada). However, despite Brazil's dominance in the supply of ferro-niobium, one observes a moderate degree of market power that can reflect the great importance of other minerals in composing the high performance alloys.

5. Final Comments

This paper assessed the intensity of competition in the international market for niobium in the U.S. destination market. The adopted approach builds on country-level residual demand estimation as advanced by Goldberg and Knetter (1999) and considers source markets in Brazil and Canada. However, in contrast with the related empirical literature, we explicitly address the non-stationarities of the data.

The results for the residual demand of Brazil in the U.S. destination market were generally satisfactory from a statistical point of view. For the main parameter of interest, the residual demand elasticity, the evidence suggested a significant but moderate degree of market power despite the strong dominance of Brazil vis à vis Canada in ferro-niobium supply. The result can, in principle, be attributed to the relevant roles of some alternative mineral (for example, tantalum and vanadium) in composing high performance alloys either in substitutive or complementary fashion with ferro-niobium, but this potential of the latter has not yet been fully explored.

A more detailed investigation of this sector in terms of the association with alternative minerals is somewhat restricted by data availability. Nevertheless, it is possible to undertake studies for other destination markets, such as the European Union and China.

Moreover, other products that are derived from niobium could be investigated. In particular, niobium oxide, given its purity and more limited possibilities of substitution, may potentially give rise to a more substantial degree of market power.

Finally, the analysis could also advance by considering possible dynamic specifications for residual demand.

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Table A1

SL test for unit root with endogenous structural break (in level) – prices and quantities

Variable	**Model**	**Break type**	**Break Date**	**Test Statistic**	**Lags**
qnb^{br}	C	rational shift	2008:01	-3,98***	2
qnb^{br}	C,T	rational shift	2008:01	-5,75***	2
pnb^{br}	C	rational shift	2006:07	-1,62	2
pnb^{br}	C,T	rational shift	2006:07	-1,61	2
Δpnb^{br}	C	rational shift	2004:08	-5,29***	2
Δpnb^{br}	C,T	rational shift	2004:08	-5,12***	2

Notes:

(a)"C" denotes a constant and "T" refers to a deterministic trend.

(b) (***) significance at the 1% level; (**) significance at the 5% level; (*) significance at the 10% level. Maximum lag set at 10 and optimal lag chosen by the AIC.

(c) critical values of the SL test are provided by Lanne et al. (2002) for 3 types of endogenous structural breaks: (i) model with constant: -3.48 (1%); -2.88 (5%) and -2.58 (10%); (ii) models with constant and deterministic trend: -3.55 (1%); -3.03 (5%) e -2.76 (10%).

Table A2

SL test for unit root with endogenous structural break (in level) - demand and cost shifters

Variable	Model	Break type	Break date	Test statatistic	Lags
pta	C	rational shift	2008:04	-2,33	2
pta	C,T	rational shift	2008:04	-2,65**	2
Δpta	C	rational shift	2008 :06	-4,01***	2
Δpta	C,T	rational shift	2008 :06	-4,35***	2
pva	C	rational shift	2008:06	-1,76	2
pva	C,T	rational shift	2008:06	-2,18	2
Δpva	C	rational shift	2004:03	-3,60***	2
Δpva	C,T	rational shift	2004:03	-4,17***	2
$e^{can/usa}$	C	rational shift	2014:09	-2,26	2
$e^{can/usa}$	C,T	rational shift	2007:09	-1,19	2
$\Delta e^{can/usa}$	C	rational shift	2007:09	-5,78***	2
$\Delta e^{can/usa}$	C,T	rational shift	2007:09	-6,46***	2
w^{br}	C	rational shift	2006:03	-2,04	2
w^{br}	C,T	rational shift	2006:03	-4,32***	2
$e^{br/eua}$	C	rational Shift	2007:10	-1,05	2
$e^{br/eua}$	C,T	rational shift	2007:10	-1,40	2
$\Delta e^{br/eua}$	C	rational shift	2010:01	-5,79***	2
$\Delta e^{br/eua}$	C,T	rational shift	2010:01	-5,08***	2
pw^{br}	C	rational shift	2005:02	-5,27***	2
pw^{br}	C,T	rational shift	2005:02	-5,67***	2

Notes:

(a)“C” denotes a constant and “T” refers to a deterministic trend.

(b) (***) significance at the 1% level; (**) significance at the 5% level; (*) significance at the 10% level. Maximum lag set at 10 and optimal lag chosen by the AIC.

(c) critical values of the SL test are provided by Lanne et al. (2002) for 3 types of endogenous structural breaks: (i) model with constant: -3.48 (1%); -2.88 (5%) and -2.58 (10%); (ii) models with constant and deterministic trend: -3.55 (1%); -3.03 (5%) e -2.76 (10%).

Table 1

Niobium: main producers and applications

Product	**Key Producers**	**% of Nb Market**	**Applications**	**Main markets**
Standard grade ferroniobium (HSLA FeNb) ~60% Nb content	▪ CBMM ▪ Anglo American ▪ Niobec	92,2%	▪ high strength low alloy steel (HSLA) ▪ stainless steel ▪ heat resistant steels	▪ automotive industry ▪ heavy engineering and infrastructure ▪ petrochemical sector
Vacuum Grade Ferroniobium (VG FeNb)	▪ CBMM	3,0%	▪ superalloys	▪ aircraft engines ▪ power generation ▪ petrochemical sector
Niobium metals and alloys ~50-65% Nb content	▪ CBMM	3,4%	▪ superconductors	▪ particle accelerators ▪ magnetic resonance imaging ▪ various small tonnage uses
Niobium chemicals > 99% Nb content	▪ CBMM	3,4%	Functional ceramics catalysts	▪ optical ▪ electronics

Fonte: Niobec[14]

[14] Accessed in 26/09/2017 at http://niobec.com/en/about/niobium/

Table 2

Data description

Variables	Description	Source
pnb^{br}	Logarithm of ferroniobium alloy price exported by Brazil to the U.S (dollar per kg)	USA TRADE - Census Bureau
qnb^{br}	Logarithm of quantity of ferroniobium alloy exported by Brazil to the U.S. in kg	USA TRADE - Census Bureau
$e^{can/usa}$	Logarithm of the nominal exchange rate (C$/US$)	Federal Reserve
w^{br}	Logarithm of the index of real wage [2010/01=100] for the basic metallurgy sector in Brazil	Brazilian Statistical Bureau (IBGE)
pw^{br}	Logarithm of the industrial energy distribution tariff by the main firm in the state of Minas Gerais, Brazil (CEMIG) (R$ per MegaWatt)	Brazilian Regulatory Agency for Energy (ANEEL)
$e^{br/eua}$	Logarithm of the nominal exchange rate (R$/US$)	Brazilian Central Bank (BACEN)
pv	Logarithm of the price of vanadium (dollar per kg)	USA TRADE - Census Bureau
pta	Logarithm of the price of tantalum (dollar per kg)	USA TRADE - Census Bureau

Note: all variables that are index numbers were put in the common base period of 2010:1

Table 3

Summary statistics

Variable	No. of observations	Mean	Std Dev	Minimum	Maximum
pnb^{usa}	154	20.91	7.91	9.26	29.73
qnb^{br}	154	753424	293545	17424	1587.510
$e^{can/usa}$	154	1.13	0.13	0.95	1.51
w^{br}	154	170.40	48.95	74.50	286.06
pw^{br}	154	470.60	99.20	219.92	638.74
$e^{br/eua}$	154	2.28	0.55	1.56	3.90
pv	154	29.10	14.18	7.83	78.44
pta	154	0.12	0.03	0.05	0.21

O separador de decimais é ponto e não vírgula e não se coloca separador de milhares, fiquei na dúvida dos valores

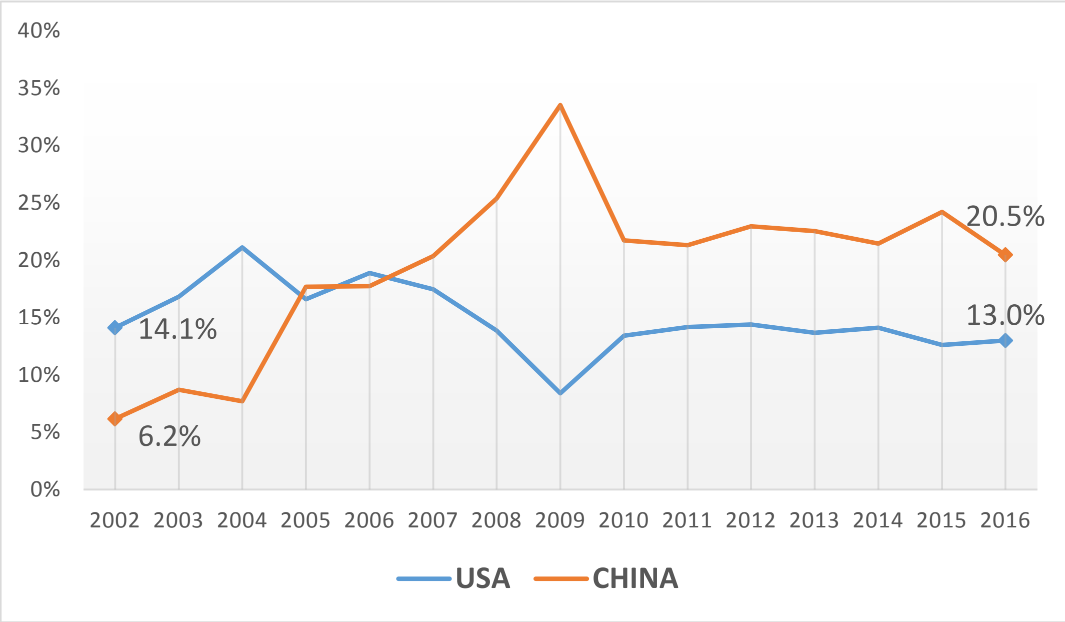
Table 4

Residual demand estimation results by two stage least squares (2SLS)– U.S. destination market, Brazilian exports of ferro-niobium alloy [2002.1-2016.5]

Dependent variable: pnb^{br}		no. of observations: 151
regressor	**coefficient**	**p-value**
constant	6.727	0.000
qnb^{br}	-0.500	0.000
trend	0.006	0.000
DSB	0.143	0.022
pta**(-1)**	-0.103	0.029
pva**(-2)**	0.132	0.095
$e^{can/usa}$ **(-3)**	-2.300	0.000
Instrumented: qnb^{br}		
included instruments: trend, DSB, e^{can}(-3), pta(-1), pva(-2)		
excluded instruments: w^{br}(-1), en^{br}(-1), e^{br}		
F(6,144) = 79,96 (p-value: 0.000)	centered R^2 = 0.725	Sargan statistic $\chi^2(2)$ = 2.703 [p-value: 0.259)

Figure 1

Share of Brazilian ferro-niobium exports for selected destination markets



Source: Aliceweb/Secretaria de Comércio Exterior de onde, de que ministério, do Brasil?