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Using time series analysis to understand price setting

Edgard Antonio Pereira

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Instituto de Economia

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Using time series analysis to understand price setting [1]

Edgard Antonio Pereira [2]

Abstract

This paper analyses the behavior of the Brazilian rebar industry prices during the period from 2000 to 2010. Instead of proposing a model for the price setting process in this industry, the paper uses time series analysis to identify the existence of a pattern for adjustments in domestic rebar prices. The conclusion is that the existence of a stable long-run relation can be established between domestic prices, the main raw materials and the international prices of rebar.

Keywords: Price setting; Rebar industry; Cointegration; Granger causality test.

Contents

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(1) An earlier version of this study had the contribution of Ricardo Avelino and Rodrigo Hussne.

(2) Economic Theory Department, University of Campinas, Unicamp, Brazil. E-mail: edgard@eco.unicamp.br.

Introduction

This paper analyses the behavior of the domestic (Brazilian) and international price of rebar and of its main raw materials in an attempt to identify the existence of a pattern for the variation of domestic prices. More precisely, econometrics tests are performed to evaluate the existence of a long-run stable relation between costs, domestic prices and international prices in this market.

The empirical approach to investigate the price setting process in a specific market derives from the assumption that price decision of the firm usually follows a rule, a pattern, which eases the decision and diminishes the risk of having unexpected price responses of competitors.

This *conventional* behavior may take place particularly when the market in reference is not facing structural transformation. This means that for mature industries, considering not only the technological aspects but also strategic ones, to preempt new entrants, for example, the price rule adopted could be sustained for a long period of time. What initially should be a short-run tool for price adjustments turns into the long-run price mechanism. This possible result will emerge depending on how efficient the rule proves itself to be.

The economic literature is abound with theories to answer why firms do what they do in terms of price setting. All of them make a lot of restrictive hypothesis and build models which should reproduce the price decision rationale and then try to see if the actual numbers fit the model.

The reverse could bring better results. First, see if there is some pattern in the observed facts. Then make some hypothesis on what could explain the adoption of such pattern.

The present paper follows the last approach. Without any previous model, the prices series are studied directly looking for regularities and relations between the variables. As result it was possible to demonstrate the existence of a pattern in the price setting process in the Brazilian rebar industry.

The paper is organized as follows: following this Introduction, section 1 presents briefly the hypothesis to be tested. Section 2 shows the behavior of prices in the Brazilian and international rebar market and section 3 presents the results of the econometric tests. The last section summarizes the paper's conclusions.

1 Market power and price setting

Setting prices is one the most difficult decisions made by the companies. It involves cost analysis, strategic behavior, expectations on the possible responses of competitors (TIROLE, 1988)[3] and the long run market profitability (Milgrom and Roberts, 1982)[4]. It also depends on the degree of concentration of the market, i.e., the market power of the firm (Sherer and Ross, 1990).

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(3) See especially chapters 5 and 6.

(4) See also (Baumol, 1988).

Evidently the length of the pricing debate goes far beyond the limits of this paper. The focus here will be an application of a specific technique – time series analysis – to understand the process of changing prices over time. The hypothesis is that when a market faces a period of relative structural stability - which means no major changes in the productive process, spectrum of products, numbers of the participants firms in the market, companies tend to set prices that basically respond to the cost and demand variations.

This rule – following cost and demand – seems to be an efficient way to coordinate price decisions in concentrated markets, in order to avoid disruptive price wars and to preserve the long run profitability of the market, without violating antitrust laws, such as cartel agreements, for example[5].

The adoption by firms in a concentrated market of this kind of rule does not mean necessarily a demonstration of market power of the firms. It could be understood as an efficient arrangement that goes beyond the limits of the firm, implying the conscious engagement of the competitors in the acceptance of a common rule to govern the price setting process.

Undoubtedly, the firm's market power is expressed in the *level* of the prices. The distance from the prices actually set to the competitive prices reflects the degree of price inelasticity, a proxy for the firm's market power. The question is: given one market which is structurally stable in a certain moment of the time, what guides the price variations? If the answer is cost and demand movements, the conclusion should be that firms are not using their market power to behave noncompetitively. Or, in other words, firms behave competitively, no matter their market power.

This is because the implementation in concentrated markets of a common agreement – such as follow cost and demand –is the equivalent to the *take the market price* in the competitive markets. In this sense, the established unwritten rule permits the same efficient result in two completely different market structures.

The implication of the acceptance of the price setting rule as a legitimate mechanism to govern the price decision among competitors is that it is not needed to identify the theoretical model of price adjustment in a specific market or even to precisely delimit the boundaries of the market to evaluate its degree of competition[6]. The analysis could be as simple as *look what they do*. In other words, find the rule. If there is evidence that the prices follow cost and demand variations, then the conclusion must be that the firms act competitively[7].

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(5) The legitimacy of this price setting behavior is recognized by the antitrust authorities by the *parallelism plus* theory, which stands for the proposition that there is no anticompetitive practice if the conscious price parallelism is not accompanied by an another fact – the *plus* - which proves that the firm's behavior intentionally aims to harm market competition.

(6) This last implication has important impact on the procedures of an antitrust investigation. Every antitrust analysis starts from the delimitation of the relevant markets under investigation. This first phase of the process may take a long time and demand a significant amount of data to determine the substitutability between products marketed by the firm under analysis and the products candidates to be participants of the market.

(7) As said earlier (note 5) this conclusion would not follow if there is proof of the existence of an anticompetitive agreement.

This *find the rule* approach seems to be even more applicable to less developed open economies. The competition from imported goods tends to have a significant impact on the price setting process for companies which operate in internationalized markets. Even if actual volume of importation is not considerable, the simple possibility of importation is able to interfere in price decision. In some cases, the threat of external competition tends to be more decisive than local production.

In conclusion, it can be argued that instead of attempting to adapt the market to be analyzed to a theoretical model previously defined, the analyst should start by looking at price series and trying to identify a pattern of the price evolution.

In the present paper this approach is applied to the Brazilian rebar industry. The ten year evolution of prices for this product is analyzed in order to identify the existence of a long-run stable relation between domestic prices of rebar, the price of the most important components of its production cost and international rebar prices.

2 Rebar Market

Steel industry products can be classified into four main steel segments: common flat steel, long steel, semi-finished and special steels, with first two corresponding to the majority of steel production in Brazil. The differences between these segments primarily concern the physical characteristics and applications of the respective products.

Rebar is a long, ribbed, rolled steel used exclusively in construction, being a specific by-product of common long steel. Rebar is a homogeneous product, with no evidence of processes of differentiation, segmentation or implementation of technical improvements. That is, as with other commodities, competition in the market for rebar occurs primarily through prices, which vary according to variations in supply and demand.

Performance of the rebar market is closely related to the performance of the construction industry, a sector closely linked to the macroeconomic performance of the economy.

In recent years, the steel industry has undergone significant and important changes, a particular effect of substantial expansion of the Chinese economy and its increasing involvement in international trade. Therefore, not only the final products, but also the inputs used in their manufacture have had their prices increased due to the increase in demand.

After rapid growth in the postwar period from 1973 to 2000, global production of crude steel has stabilized, characterizing the steel industry as a mature activity with relatively low growth. However, since 2001, China's growth above 9% per annum has boosted global demand for steel and the main raw materials used in its manufacturing process - particularly iron ore and scrap - a situation that is changing in respect to product prices (CROSSETI, 2005).

Since 1978, when the Chinese government started economic opening to revitalize the domestic economy, the country has been converted into a heavy consumer of raw materials and inputs, increasing production and prices of several commodities, including iron ore and steel. This intense movement of imports was a result of two decades of high investment, especially by the government, and strong inflow of foreign direct investment, creating a vibrant industrial park. The rapid growth in China has generated a need for the production of large volumes of steel to satisfy the creation and expansion of industrial units and infrastructure. Rapid urbanization has caused a housing boom that has pushed even further production growth, making China the largest consumer of steel globally.

The trade flow generated by strong growth in Chinese imports has raised the prices of these products around the globe, stimulating the expansion of capacity. These investments resulted in increases in capacity and some substitution of imports from China in 2004. On the other hand, these new capacities pushed the demand for raw materials in the world, which sped up the prices of key inputs such as iron ore and coal (LME, 2004).

On the Brazilian supply side, the investment cycle that occurred in the domestic steel industry between 1994 and 2003 resulted in no significant increase in the total productive capacity, although the investments were given priority and resulted in increased rolling capacity (CROSSETI, 2005). Thus, from the more than proportional increase in foreign demand for steel products, the sale prices of the various types of steel in the domestic market rose during this period. This is because, as will be shown below, there was not only significant increase in international prices of final products (e.g. rebar), but also the main raw materials used in its manufacture.

2.1 Rebar prices

The analysis of the evolution of domestic and international prices for rebar and the main raw materials used in its manufacture is a first step to identify the economic rationale for prices charged for rebar in sales to customers in the Brazilian domestic market. In addition to considering the price of the domestic market, as illustrated above, it is clear that the domestic prices were marked by the prices of raw materials used in the manufacture of rebar and the international prices of products.

The data used in this study consists of a historic series of monthly domestic and international prices for rebar and domestic prices for the main raw materials used in the manufacture of rebar (metallic load, pig iron and scrap), covering the period between January 2000 and December 2010.[8] The price of raw materials is originally expressed in Reais per ton and the international price is in dollars per ton. The spot price of rebar in the U.S. market is used as a proxy for the international price.

To make them comparable, the international price of rebar was converted into Reais per ton using the average monthly exchange rate, calculated as the average of buy and sell rates obtained from the website of the Institute of Applied Economic Research (IPEA)[9]. The average monthly domestic price of rebar, in turn, was calculated based on all sales to companies affiliated with the association of

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8) Except when indicated otherwise, all the data used in this paper were provided by the Brazilian rebar industry.

(9) Source: Central Bank of Brazil

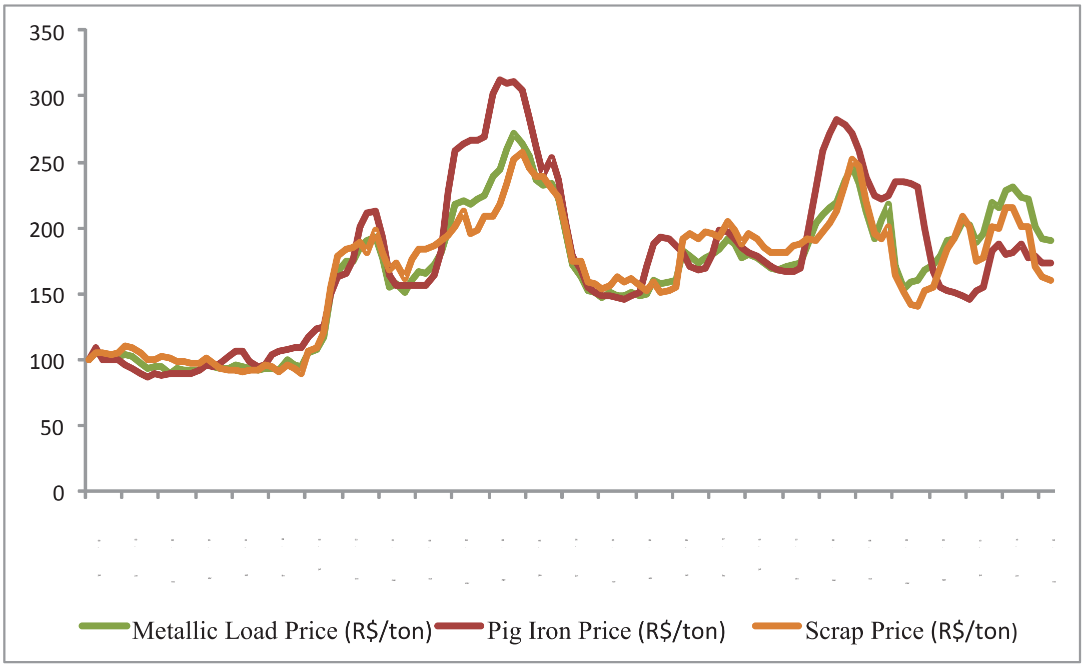
construction companies**.** Based on 37,975 sales invoices for the period between January 2000 and December 2010, the sales of rebar CA 50 were selected[10]. Then, for each month, a price was built weighing the unit value of each sale by the quantity sold. Finally, all the series were deflated using the consumer price index (IPCA), in order to purge the effect of inflation and make the values comparable over time. Henceforth, all prices are expressed in real terms.

2.2 Domestic Price of Rebar and Price of Raw Materials

If the domestic market prices were set in a competitive environment, it is expected that they were adjusted over the time to adjust margins in the variations in raw material prices. In other words, it is expected that if the domestic price is compatible with the competitive standard, the domestic price of rebar must have a long-run stable relationship to the prices of raw materials.

Figure 1 below shows the evolution of the domestic price of raw materials during the period analyzed. To facilitate comparison, the values were normalized, setting the baseline at 100. Some facts are worth mentioning.

Figure 1
Evolution of Prices of Raw Materials
(R$/ton)



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[10] Although internationally the CA 60 is the standard rebar product, in Brazil the technical rules specify CA-50 rebar as standard. Sales of CA-60 in the Brazilian rebar market made during the analysis period are negligible compared to sales of the CA-50 rebar.

First, the strong rise in prices of metallic load, pig iron and scrap, especially from mid-2002. From January 2000 to June 2002, prices of these items remained stable. The prices of metallic load and scrap in real terms, fell 6% and 10% respectively, while the price of pig iron increased by 9%.

Between June 2002 and December 2010, there was a substantial increase in raw material prices. The increases ranged from 59% for pig iron and 103% for metallic load. This structural change resulted from accelerated growth and consequent increase in Chinese demand for raw materials like iron ore. From 2004, there also was more vigorous growth of the domestic economy. Between 2000 and 2003, for example, according to data from the Brazilian Institute of Geography and Statistics (IBGE), GDP grew at an average annual rate of 1.7%. But between 2003 and 2009, the average annual GDP growth reached 4.0%.

Note that the prices of the three items – metallic load, pig iron and scrap - vary closely. Although, at times, they may become further apart, these deviations are temporary and eliminated in the long term.

Figures 2 to 4 below show the evolution of the price of rebar and three of its major components.

Figure 2
Evolution of the Domestic Price of Rebar CA 50 and the price of Metallic Load (R$/ton)

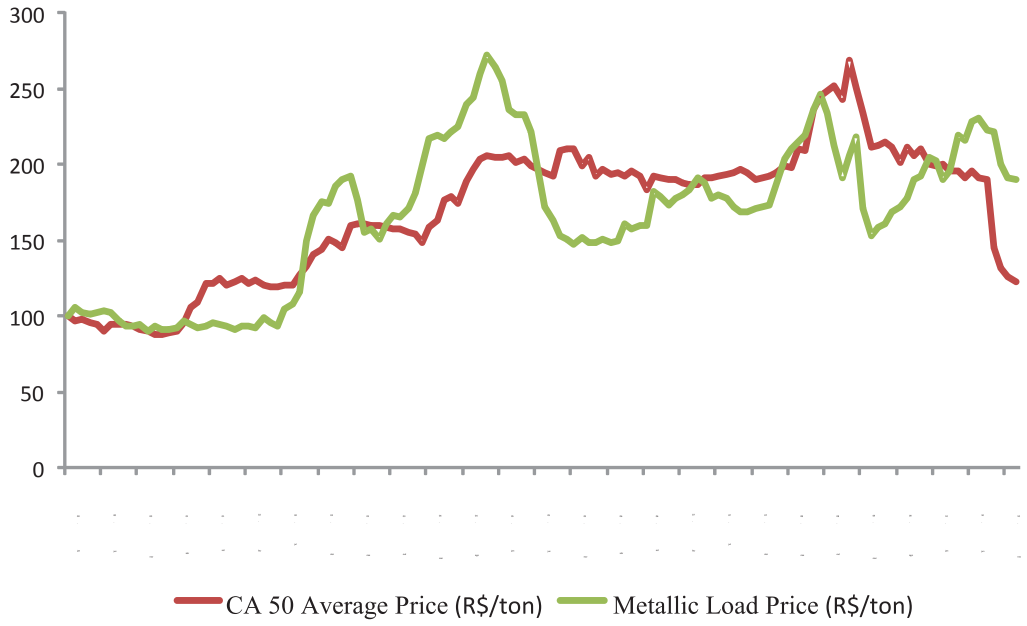

Figure 3
Evolution of the Domestic Price of Rebar CA 50 and the Price of Scrap (U.S. $ / ton)

Figure 4
Evolution of the Domestic Price of Rebar CA 50 and the Price of Pig Iron (R$/ton)

Variations in the domestic price of rebar tend to be associated with changes in the prices of metallic load, scrap and pig iron. The price of rebar has also remained relatively stable between January 2000 and June 2002, rising 19%. After June 2002, there was a significant increase in the domestic price of rebar, which reached 125% by January 2009, resulting from strong growth in demand for steel and the raw materials used in its manufacturing process during the period.

The table below shows the correlation between commodity prices and domestic prices of rebar[11].

Table 1
Correlation of the Average Price of Rebar in the Internal Market with the Price of Raw Materials

Price Series	Correlation Coefficient
Metallic Load Price	0.8725
Pig Iron Price	0.8398
Scrap Price	0.8892

The correlation between the domestic price and the price of scrap is equal to 0.8892, which shows that about 89% of variations in the domestic price of rebar are associated with variations in the price of metallic load. The correlation coefficients between the domestic price of rebar and the prices of pig iron and metallic load are also quite high, equal to 84% and 87% respectively.

That is, there is a primary indication that the evolution of domestic prices has followed the tendency of raw material prices. This hypothesis is formally tested using time series econometric techniques in next section.

2.3 Domestic Price and International Price of Rebar

Besides the relationship between the price of rebar and the cost of raw materials, if the prices in the domestic market are competitively determined, it is also expected that they will be influenced by the price of product in the international market, which presents itself as a potential replacement.

Figure 5 shows the evolution of domestic and international prices between January 2000 and December 2010. For the whole period, it should be noted the faster growth of domestic demand for rebar *vis-à-vis* growth in international demand. This is due in large part to the rapid growth of the construction industry in Brazil in recent years. Thus, given the different dynamics of demand, it is expected, *coeteris paribus*, the evolution of rebar prices would be different in the two markets.

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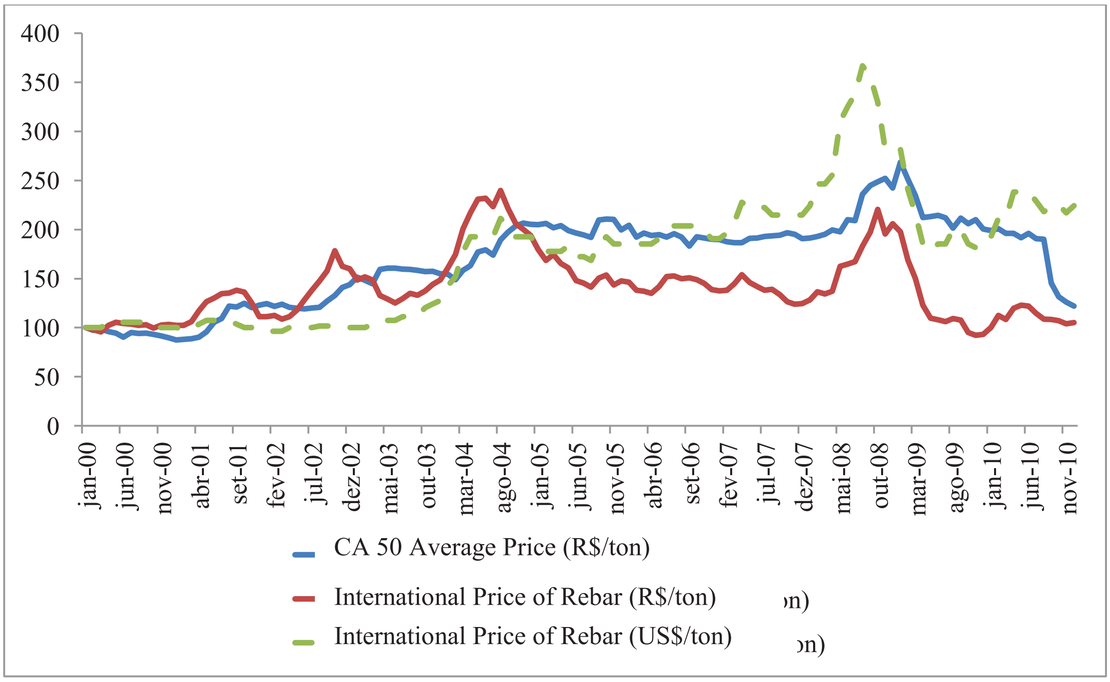
(11) The correlation coefficient is a measure of linear association between two variables, including between -1.00 and +1.00, which indicates the greater or lesser extent in which the two events are linked. A coefficient equal to 1.00 (positive or negative) indicates a perfect correlation (positive or negative); 0.00 indicates no correlation.

Figure 5
Evolution of the Domestic Price of Rebar CA 50 and the Internal Rebar Price (R$ /ton and U.S.$/ton)



From early 2000 to late 2003, the price trajectories are quite similar. From 2004 onwards, there are basically three distinct periods. In the first one, which extends to the third quarter of 2004, the change in the international price exceeds the domestic price.

From late 2004 until the third quarter of 2008, the trend is reversed. The domestic price is persistently above the international price in Reais, although a trend toward distancing of prices is not noted. After the third quarter of 2008, however, with the worsening international financial crisis, there is a shift in trajectories. Initially, the domestic price decreased 20% from September 2008 to June 2010, while the real international price declined 38% over the same period. From the second half of 2010, the domestic price dropped more than the international price, respectively 38% and 14% between June and December 2010.

There are two main factors that explain this recent shift. First, the difference of the impact of the international crisis on developed and developing countries. Brazil's GDP, at the height of the crisis in 2009, contracted by 0.2%. The U.S. economy, in the same period dropped by 2.6%, after remaining stagnant in 2008. Moreover, one must consider the speed at which economies have emerged from impact of the crisis. The developed economies, in addition to being hit hardest by the crisis, have recovered more slowly. On the other hand, Brazilian industrial production in August 2010, for example, in the seasonally adjusted series, was only 1.5% below the record level seen in the pre-crisis period in July

2007. Industrial production in the U.S., by contrast, despite the recovery, was still 5.6% below the peak recorded in September 2007[12].

Second, note the behavior of nominal Real/Dollar exchange in the post-crisis period. The Dollar, after reaching R$ 2.38 in late February 2009 amid capital flight caused by the crisis, has appreciated continuously. In late August 2010, the exchange rate was R$ 1.76. This abrupt appreciation of the Dollar obviously contributes to a cheapening of rebar when converting the price in Dollars to Reais.

This effect of the exchange rate becomes clearer when one compares the evolution of domestic prices with international price developments in Dollars (dotted line in the figure above). When denominated in the currency in which it is traded in the international market, the international price of rebar rises more sharply than the domestic price in Reais. That is, in the domestic market, where prices are traded and denominated in Reais, the high international price of rebar was less acute in view of the dampening caused by the appreciation of the Real against the Dollar.

Variations in the international price of rebar and raw material prices not only were similar to changes in the domestic price but also occurred promptly.

The correlation coefficient between the domestic and international prices of rebar is 0.7594, which is very significant, although lower than the correlation between the domestic price of rebar and the prices of raw materials. The lower correlation coefficient results from the shift of the series after the third quarter of 2008, as highlighted.

Considering the relationship between domestic and international prices, there is an indication that the domestic prices follow the international ones. This hypothesis will be also tested formally using time series econometric techniques in the next section.

3 Econometric Analysis of Changes in the Price of Rebar

This section is divided into three parts. The first outlines the results of tests for the presence of unit root in the series of raw material prices and domestic and international prices of rebar. Next, the results of the Johansen cointegration test are presented, which aims to determine the existence of a long-run stable relationship between the series. Finally, the evidence from the Granger causality test is detailed, which aims to evaluate whether variations in commodity prices and international prices help predict future developments in the domestic price of rebar.

3.1 Dickey-Fuller Generalized Unit Root Test

Statistical analysis of the series of prices is aimed at determining, by means of the Dickey-Fuller generalized test (ELLIOTT, Rothenberg and Stock, 1996), if the trajectories of the logarithms of the series are described by a stationary or non-stationary process[13]. The option of working with the logarithm of the series is due to the fact that the growth rate does not present a tendency to increase or decrease

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(12) Sources: Ipeadata and Federal Reserve Bank of St. Louis.

(13) Formally, a variable yt would be stationary if E(yt)=μ, Var(εt)=σ2 and Cov(yt, yt-j)=f(j), j≠0. In other words, if the mean and variance are constant and if the covariance between two observations at different times is a function only of the extent of the range that separates them, but not the period in which they are observed.

over time, unlike the magnitude of the difference between two months, which tends to grow. Therefore, it is likely that variations in the logarithm of the series are stationary, as opposed to variations in the level of the variables.

This initial analysis is crucial because the standard deviations, confidence intervals and conventional hypothesis testing are not valid if the series is not stationary. Moreover, it is noteworthy that, in general, a regression between two variables that have a non-stationary growth trend over time shows a high R^2 even if there is no relationship between them. This problem is known in literature as spurious regression (Granger and Newbold, 1974).

The Dickey-Fuller generalized test, as the name suggests, is a generalization of the test originally proposed by Dickey and Fuller (1979). In finite samples, it leads to a higher power of the test compared to the original test, that is, it has a higher probability of rejecting the hypothesis being tested (null hypothesis) when this assumption is false. Both in the original test and in the generalized test, the null hypothesis occurs when there is a unit root, i.e. the variable is described by a non-stationary process. The alternative hypothesis is that the process is stationary. The critical values of the test, which must be compared with the observed values of statistics to determine if the hypothesis being tested must either be rejected or not, are able to be calculated using the appropriate values reported by Mackinnon (1991, 1996). If the value observed from the statistics is less than the critical value, the null hypothesis is rejected. Otherwise it is not rejected.

Table 2 below shows the results of the Dickey-Fuller test generalized for the logarithm of raw material prices, domestic prices of CA 50 rebar and the international price in Reais. To determine the number of lags of the dependent variable included among the explanatory variables, the sequential t-test proposed by NG and Perron (1995) was used.

For the six series, it is not possible to reject the null hypothesis on the existence of a unit root, even when adopting the significance level of 10%, because the observed value of the statistic exceeds the critical value in all cases. Therefore, there is strong evidence that the logarithms of prices are non-stationary processes.

Table 2
Generalized Dickey-Fuller Unit Root Test in Series Prices

Variable	Statistics	Lags	Critical value 10%
International Price	-1.538	6	-2.629
Metallic Load Price	-1.766	7	-2.612
Pig Iron Price	-1.610	7	-2.612
Scrap Price	-2.110	3	-2.674
Domestic Price	-0.936	2	-2.687

3.2 Johansen Cointegration Test

Since it is not possible to reject the hypothesis that the logarithm series of prices exhibit a unit root, we move on to the next stage of analysis, which is to examine whether there is a long-run equilibrium relationship between the international price and the domestic price of rebar and the prices of raw materials. If there is a long-run stable relationship between the variables, they by definition cointegrate. Formally, the variables cointegrate if they are not stationary and there is a linear combination between them which is stationary.

The Johansen (1988, 1991) procedure offers a convenient way to test whether two or more series cointegrate, assuming it is not possible to reject the hypothesis that each variable has a unit root. The Johansen test has some advantages over the cointegration test of Engle and Granger (1987). One limitation of the Engle and Granger test results from the fact that it involves an estimator obtained in two stages, which means that any error introduced in the first stage is transferred to the second stage. Another disadvantage is that the results are sensitive to the normalization adopted and can result in conflicting conclusions, depending on the variable chosen as the dependent variable. The Johansen test result, by contrast, is based on estimates of the matrix rank and its eigenvalues, obtained in a single stage, and is invariant to the choice of the variable selected for normalization.

Table 3 presents the results of the Johansen test on the hypothesis that the domestic price, international price and the prices of pig iron and scrap and metallic load cointegrate simultaneously. The Lagrange multiplier test indicates that the inclusion of four lags of the dependent variable among the regressors in the autoregressive vector model with the variables in level is enough to eliminate the autocorrelation of errors.

It is noted in table 3 that both the trace statistic and the maximum eigenvalue statistics provide evidence that at most one of the eigenvalues is different from zero at a conventional significance level of 5%. The values of the statistics associated with the hypothesis that there is no cointegration relation of 86.02 and 43.88 are higher than the critical significance level of 5%, 68.52 and 33.46. On the other hand, the values of the statistics associated with the hypothesis that there is only one cointegration relation of 42.15 and 26.75, values are lower than the critical significance level of 5%, of 47.21 and 27.07.

Table 3
Johansen Cointegration Test for Domestic Price of CA 50 Rebar, Prices of Raw Materials and International Price of Rebar

4 Lags in Variable Level			
Trace Statistics			
Cointegration Vectors	Eigenvalue	Statistics	Critical Value 5%
None	0.29802	86.0220	68.52
At most 1*	0.19401	42.1447	47.21
At most 2	0.07953	15.3992	29.68
At most 3	0.03266	5.1230	15.41
At most 4	0.00807	1.0052	3.76
Maximum Eigenvalue Statistics			
Cointegration Vectors	Eigenvalue	Statistics	Critical Value 5%
None	0.29802	43.8773	33.46
At most 1*	0.19401	26.7455	27.07
At most 2	0.07953	10.2763	20.97
At most 3	0.03266	4.1178	14.07
At most 4	0.00807	1.0052	3.76

Note: * Indicates non-rejection of the null hypothesis at a significance level of 5%.

3.3 Granger Causality Test

This subsection examines the extent to which variations in the price of raw materials and the international price of rebar precede changes in the domestic price. Unlike what the name suggests, the test does not aim to evaluate whether there is a causal relationship between raw material prices, the international price and domestic price of rebar in the usual sense of the term. The test only shows whether changes in past values of raw material prices and international prices have some additional predictive value on the contemporary domestic price of rebar, controlled by the lagged values of the domestic price.

In general, it is preferable to select a number of lags bigger than a small number for the test, because the concept of Granger causality is related to the relevance of all data passed. Therefore, one must use a number of lags corresponding to a reasonable assumption about the longest period of time that one of the variables can help predict the other. The conservative strategy was adopted of including a maximum of 12 lags of the variables. Additionally, the number of lags included was varied, in order to test the robustness of the results.

Tables 4 and 5 show the results of the test for the hypothesis that the international price and the prices of raw materials do not Granger-cause the domestic price of rebar. The results in Table 4 indicate that variations in international prices can help predict the domestic price. The p-value associated with the test is always less than 0.6% regardless of the number of lags considered, indicating that there is a clear improvement of the domestic price forecasts by including past values of the international price.

Table 4
Granger Causality Test
Domestic Price x International Price

Dependent Variable: Domestic Price			
Excluded Variable	Statistics	Lags	P Value
International Price	27.475	8	0.001
International Price	29.494	9	0.001
International Price	28,589	10	0.001
International Price	29.279	11	0.002
International Price	27.815	12	0.006

In turn, Table 5 presents evidence that raw material prices Granger-cause the domestic price. The p-value is always less than 0.4%. Therefore, there is strong evidence that the prices of raw materials also help predict the domestic price of rebar in the future.

Table 5
Granger Causality Test
Domestic Price x Price of Raw Materials

Dependent Variable: Domestic Price			
Excluded Variable	Statistics	Lags	P Value
Prices of Raw Materials	46.094	8	0.004
Prices of Raw Materials	52.330	9	0.002
Prices of Raw Materials	57.627	10	0.002
Prices of Raw Materials	84.312	11	0.000
Prices of Raw Materials	97.750	12	0.000

Similar conclusions are obtained when considering the combined effects of the international price and the prices of raw materials on the domestic price of rebar. According to Table 6, the hypothesis that the international price and the prices of raw materials, taken together, do not help predict the domestic price can be safely rejected at a significance level of 5%, as the p-value is always close to 0.0%, regardless of the number of lags.

Table 6
Granger Causality Test
Domestic Price x Price of Raw Materials and International Price

Dependent Variable: Domestic Price			
Excluded Variable	Statistics	Lags	P Value
International Price and Prices of Raw Materials	80.900	8	0.000
International Price and Prices of Raw Materials	88.402	9	0.000
International Price and Prices of Raw Materials	91.796	10	0.000
International Price and Prices of Raw Materials	110.730	11	0.000
International Price and Prices of Raw Materials	128.52	12	0.000

Conclusion

This paper analyzed the evolution of domestic and international prices of rebar. By examining the series of prices in Brazil and abroad, it was shown that the adjustments made in domestic prices were closely related to the behavior of the raw materials prices. Between 2000 and 2010, the domestic price of rebar increased 89% in real terms, while increases in raw material prices were between 88% and 123%.

The increases not only had a similar magnitude but also occurred on close dates. The correlation between the domestic price of rebar and the prices of metallic load, pig iron and scrap is significant and exceeds 75%.

The existence of a long-run stable relation between prices of raw materials, the international price and domestic price of rebar and if the variations in raw material prices and international prices help predict the future domestic price of rebar were examined using econometric techniques. The results confirm the initial impression that the adjustments in domestic prices of rebar reflect variations in costs of raw materials and in the international price. The Johansen cointegration test provides unequivocal evidence that there is a long-run stable relation between prices of raw materials, the international price and domestic price of rebar. Additionally, one can conclude from the results of the Granger causality test that variations in commodity prices and international prices help predict the future evolution of the domestic price of rebar.

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Exhibit

This exhibit formally describes the econometric methodology used to analyze the relationship between international and domestic prices of rebar and the prices of raw materials. More precisely, the instruments used to assess whether there is a long-run stable relationship between the variables, and to what extent changes in the international price of rebar and commodity prices help to predict the evolution of the price of rebar in the domestic market.

The Exhibit is divided as follows. First, the Dickey-Fuller generalized unit root test (Elliott, Rothenberg and Stock, 1996) used to determine whether the series is stationary or not is described. Then the Johansen cointegration test is discussed, which aims to determine whether or not there is an equilibrium relationship between long-run series, assuming it is not possible to reject the hypothesis that they contain a unit root. Finally, the Granger causality concept is detailed, which is related to the precedence and relevance of past information for prediction, as well as the formal statistical test used to test it.

Generalized Dickey-Fuller Unit Root Test

y_t is the variable value at time t. In the simplest version of the Dickey-Fuller test, y_t is modeled as a function only of its own value lagged one period, y_{t-1} and a random shock ε_t with mean 0 and variance σ^2:

$$y_t = \rho y_{t-1} + \varepsilon_t \qquad (1)$$

The null hypothesis is that there is a unit root, that is $H_0 : \rho = 1$, and the alternative hypothesis assumes that the process is stationary, that is, $H_1 : \rho < 1$. Subtracting y_{t-1} on both sides of equation (1), it is obtained

$$\Delta y_t = \alpha y_{t-1} + \varepsilon_t, \quad \alpha = \rho - 1 \qquad (2)$$

Consequently, the null and alternative hypotheses can be expressed equivalently as $H_0 : \alpha = 0$ and $H_1 : \alpha < 0$. The Dickey-Fuller test assumes that the error term ε_t is white noise[14] . If this assumption is violated, the lags Δy_t can be included among the regressors in equation (2) to eliminate the correlation of errors. The standard deviation of the coefficient α is denoted by $se(\alpha)$t. The statistical test is based on:

$$t(\alpha) = \frac{\alpha}{se(\alpha)}$$

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[14] Formally, εt is white noise se E(εt)=0, Var(εt)= σ2 and Cov(εt, εt-j)=0, j≠0. In other words, if the average is equal to 0, the constant variance and errors observed in different periods are not correlated.

The critical values, however, do not approach the t distribution of Student. These can be calculated using the appropriated values reported by Dickey and Fuller (1979) or, alternatively, based on recent values reported by Mackinnon (1991, 1996), which are the result of a set of much more extensive simulations. In addition, MacKinnon estimates surfaces for the simulation results, which allows the calculation of critical values of the Dickey-Fuller test and associated p-values for arbitrary sample sizes. If the observed value of the statistic is less than the critical value, the null hypothesis is rejected. In contrast, if the observed value is greater than the critical value, the null hypothesis should not be rejected.

The unit root test of Dickey-Fuller can be extended to accommodate a situation in which prices grow over time. To this end, a constant in equation (1) is included:

$$y_t = \mu + \rho y_{t-1} + \varepsilon_t \qquad (3)$$

In this case, one must modify the critical values associated with the statistic. The appropriate critical values are also reported by Dickey and Fuller (1979) and Mackinnon (1991, 1996).

The Dickey-Fuller generalized test, proposed by Elliott, Rothenberg and Stock (1996), is a simple modification of the version of the Dickey-Fuller test which includes a constant among the regressors. Elliott, Rothenberg and Stock (ERS) proposed to subtract from the observations the deterministic components before running the regression used to calculate the statistics.

It defined a near difference of y_t value dependent on value a that represents the specific alternative point against which it is desirable to test the null hypothesis:

$$d(y_t \mid a) = \begin{cases} y_t & se \quad t = 1 \\ y_t - a y_{t-1} & se \quad t > 1 \end{cases}$$

Similarly, it defined $d(x_t \mid a)$ and considers then an ordinary least square regression of $d(y_t \mid a)$ in $d(x_t \mid a)$:

$$d(y_t \mid a) = d(x_t \mid a)' \delta(a) + \eta_t \qquad (4)$$

in which, x_t contains a constant and a constant and a trend. Estimators of ordinary least squares regression are denoted by $\hat{\delta}(a)$. To implement the test, it is necessary to assign a specific value to a. ERS suggests using $a = \bar{a}$

$$\bar{a} = \begin{cases} 1 - 7/T & se \quad x_t = \{1\} \\ 1 - 13{,}5/T & se \quad x_t = \{1, t\} \end{cases}$$

where T denotes the sample size. Using the estimators associated with $\bar{a}$, it defined

$$y_t^d \equiv y_t - x_t' \hat{\delta}(\bar{a}).$$

The Dickey-Fuller generalized test consists of usual regression (2) with additional lags of the dependent variable between the regressors, replacing the original data y_t by y_t^d :

$$\Delta y_t^d \equiv \alpha y_{t-1}^d + \beta_1 \Delta y_{t-1}^d + \ldots + \beta_p \Delta y_{t-p}^d + v_t$$

Note that, as y_t^d is derived from a regression y_t against x_t, x_t is not included among the regressors in the generalized Dickey-Fuller test. As in the Dickey-Fuller conventional test, the significance of t associated with the coefficient α of this regression is tested.

The Statistic t from the Generalized Dickey-Fuller test follows the distribution of Dickey-Fuller when only one constant is included among the regressors. However, when a constant and a trend are included among the explanatory variables, the asymptotic distribution differs. ERS reports the critical values of test statistics, obtained by simulation for $T = \{50,100,200,\infty\}$ in this latter case. In short, when the constant is not included among the regressors, one can use critical values simulated by MacKinnon and when a constant and a trend are included among the explanatory variables, we can interpolate the critical values simulated by ERS. The null hypothesis is rejected for the statistical values observed lower than these values.

Johansen Cointegration Test

As noted by Engle and Granger (1987), a linear combination of two or more non-stationary variables can be stationary. If there is a linear combination between them which is stationary, by definition, they cointegrate. The stationary linear combination, called the cointegrating equation, can be interpreted as a long-run equilibrium relationship among variables.

Consider a vector autoregressive model of the order p :

$$Y_t = A_1 Y_{t-1} + \ldots + A_p Y_{t-p} + BX_t + \varepsilon_t$$

where Y_t is a kx1 vector dimension containing the non-stationary series, X_t is a dx1 vector of deterministic variables and ε_t is a kx1 vector containing the innovations. This autoregressive vectorial model can be rewritten as

$$\Delta Y_t = \prod Y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta Y_{t-i} + BX_t + \varepsilon_t$$

for

$$\prod = \sum_{i=1}^{p} A_i - I$$

and

$$\Gamma_i = -\sum_{j=i+1}^{p} A_j$$

The Granger representation theorem states that if the matrix of coefficients $\prod$ has reduced rank $\tau < k$, there are matrices α and β with dimension τ x k such that $\prod = \alpha\beta'$ e $\beta' Y_t$ is stationary. τ is the number of cointegration relations. The columns β contain the corresponding cointegration vectors. As explained below, the elements α are the adjustment parameters of the error correction model.

The Johansen procedure, which is based on the estimated $\prod$ derived from an unrestricted vector autoregressive model, tests if it is possible to reject the restrictions imposed by the reduced matrix rank $\prod$. Consider the auxiliary regressions

$$\Delta Y_t = \hat{\phi}_0 + \sum_{i=1}^{p-1} \hat{\phi}_i \Delta Y_{t-i} + \hat{\phi}_p X_t + \hat{u}_t \qquad (5)$$

and

$$Y_{t-1} = \hat{\varsigma}_0 + \sum_{i=1}^{p-1} \hat{\varsigma}_i \Delta Y_{t-i} + \hat{\varsigma}_p X_t + \hat{v}_t \qquad (5)$$

and the variance-covariance sample matrices of the ordinary least squares residual samples $\hat{u}_t$ and $\hat{v}_t$:

$$\hat{\Sigma}_{vv} = \frac{1}{T}\sum_{t=1}^{T} \hat{v}_t \hat{v}_t'$$

$$\hat{\Sigma}_{uu} = \frac{1}{T}\sum_{t=1}^{T} \hat{u}_t \hat{u}_t'$$

$$\hat{\Sigma}_{uv} = \frac{1}{T}\sum_{t=1}^{T} \hat{u}_t \hat{v}_t'$$

$$\hat{\Sigma}_{vu} = \hat{\Sigma}_{uv}'$$

The cointegration test is based on k eigenvalues $\hat{\lambda}_i, i = 1,\dots,k,$ from the matrix

$$\hat{\Sigma}_{vv}^{-1}\hat{\Sigma}_{vu}\hat{\Sigma}_{uu}^{-1}\hat{\Sigma}_{uv} \qquad (5)$$

ordered so that $\hat{\lambda}_1 > \hat{\lambda}_2 > \dots > \hat{\lambda}_k$.

The null hypothesis that there are at most τ cointegration vectors, that is, $H_0 : \lambda_{\tau+1} = \lambda_{\tau+2} = \dots = \lambda_k = 0$ can be tested by trace statistics, which is given by

$$LR_{tr}(\tau \mid k) = -T\sum_{i=\tau+1}^{k} \log(1-\lambda_i)$$

The asymptotic distribution of trace statistics does not approximate the usual distribution χ^2 and depends on assumptions made on the deterministic terms. One can use the critical values reported by Osterwald-Lenum (1992), which differ slightly from those computed by Johansen and Juselius (1990). If the statistical value exceeds the critical value of the significance level adopted, the null hypothesis is rejected. Otherwise it is rejected.

On the other hand, if the goal is to test the null hypothesis that there are τ cointegrating vectors against the alternative hypothesis that there are exactly $\tau+1$ cointegrating relations ($\tau = 0,1,...,k-1$), one can use the maximum eigenvalue statistic, which is computed as

$$LR_{\max}(\tau \mid \tau+1) = -T\log(1-\lambda_{\tau+1}) = LR_{tr}(\tau \mid k) - LR_{tr}(\tau+1 \mid k)$$

Again the null hypothesis is rejected if the statistical value exceeds the critical value to the significance level adopted. Otherwise, H_0 it is not rejected.

It is important to bear in mind that the trace statistics and maximum eigenvalue can produce conflicting results. In this case, it is recommended that the estimated cointegration vectors be examined and the decision be based on the interpretation of cointegrating relations.

Granger Causality

Denote by y_{1t} and y_{2t}, respectively, the domestic price of rebar and the price of one of the raw materials or international price of rebar. Granger (1969) proposes to examine the question of whether y_{2t} causes y_{1t} evaluating how much the present value of y_{1t} can be explained by the lagged values of y_{1t} and then investigating whether the inclusion of lagged values of y_{2t} can improve predictions. y_{2t} Granger causes y_{1t} if y_{2t} helps in predicting y_{1t} or, equivalently, if in a regression of y_{1t} against lagged values of y_{1t} and y_{2t}, the coefficients associated with lagged values y_{2t} are statistically significant.

Consider bivariate regressions of the form:

$$y_{1t} = \alpha_0 + \alpha_1 y_{1,t-1} + ... + \alpha_l y_{1,t-l} + \beta_1 y_{2,t-1} + ... + \beta_l y_{2,t-l} + \varepsilon_t$$

$$y_{2t} = \gamma_0 + \gamma_1 y_{2,t-1} + ... + \gamma_l y_{2,t-l} + \theta_1 y_{1,t-1} + ... + \theta_l y_{1,t-l} + u_t$$

Formally, the hypothesis that y_{2t} does not Granger cause y_{1t} corresponds to test whether the mean squared prediction error (MSE) of y_{1t} based on past values of y_{1t} and y_{2t} is equal to the mean square error when we include as regressors only lagged values of y_{1t}, that is, corresponds to test whether

$$MSE[\hat{E}(y_{1,t+1} \mid y_{1,t}, y_{1,t-1},..., y_{2,t}, y_{2,t-1},...)] = MSE[\hat{E}(y_{1,t+1} \mid y_{1,t}, y_{1,t-1},...)]$$

For this, one can formulate the null hypothesis in terms of

$$H_0 : \beta_1 = \beta_2 = ... = \beta_l = 0$$

and test it using the usual statistic F. Denote by RSS_u and RSS_r , respectively, the sum of squared residuals of the unrestricted and restricted models. The test statistic is given by

$$S = T \frac{(RSS_u - RSS_r)/l}{RSS_r /(T - 2l - 1)}$$

and has a distribution F with l and $T - 2l - 1$ degrees of freedom. If the observed statistical value exceeds the critical value of the distribution F to the level of significance adopted, the null hypothesis is rejected.

In some cases, causality occurs in both directions, that is, y_{2t} Granger causes y_{1t} and y_{1t} Granger causes y_{2t}. It should be noted that the statement “y_{2t} Granger cause y_{1t}" does not imply that y_{1t} is the effect or the result of y_{2t}. Granger causality measures precedence and relevance of past information for prediction, but does not indicate causality in the usual sense of the term.