A STATISTICAL APPROACH TO THE PRICES VOLATILITY OF NON-FERROUS METALS

UMA ABORDAGEM ESTATÍSTICA PARA A VOLATILIDADE DOS PREÇOS DE METAIS NÃO FERROSOS

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Abstract
Analyze the Aluminum, Copper, Nickel and Zinc behavior in terms of price variation, has a notable relevance. In order to capture the conditional volatility terms and identify its reaction mechanism and persistence against shocks, the volatility asymmetry and the leverage effect it was estimated the GARCH, TARCH and EGARCH. The sum of the reaction coefficients (ARCH) with the volatility persistence coefficient (GARCH), resulted in values close to 1.0 to all the commodities, indicating that volatility shocks in prices will last for a long time. According to the TARCH results it is possible to see that the conditional variance it is not asymmetric to Aluminum and Copper. As it is possible to verify that τ it is statistically different from 0 to Nickel and Zinc, so, they have an asymmetric conditional variance. Positive shocks in Nickel and Zinc prices imply a lower volatility in comparison with negative shocks with same magnitude. Specifically to the EGARCH obtained results it possible to perceive that the Aluminum and Copper had a τ coefficient not statistically different from 0, so is does not exist asymmetry in volatility, corroborating the obtained results by the TARCH model. The Nickel and Zinc commodities presented a τ coefficient statistically different from 0 showing an asymmetric conditional variance. Accordingly, exists a different impact um by negative and positive shocks on volatility. Finally, it was not possible to verify the leverage effect in the analyzed commodities.

Key-words
Volatility, Prices, Non-ferrous metals
Resumo:
Analisar o comportamento do Alumínio, Cobre, Níquel e Zinco em termos da variação de preços, tem uma relevância notável. Para capturar os termos da volatilidade condicional e identificar o seu mecanismo de reação e persistência frente a choques, a assimetria da volatilidade e o “efeito alavancagem” foram estimados os modelos GARCH, TARCH e EGARCH. A soma dos coeficientes de reação (ARCH) com o coeficiente de persistência da volatilidade (GARCH) resultou em valores próximos de 1,0 para todas as commodities, indicando que os choques de volatilidade nos preços durarão por muito tempo. De acordo com os resultados do modelo TARCH, é possível ver que a variância condicional não é assimétrica para o Alumínio e para o Cobre. Como é possível verificar que τ é estatisticamente diferente de 0 para o Níquel e para o Zinco, então, eles têm uma variação condicional assimétrica. Os choques positivos nos preços do níquel e do zinco implicam menor volatilidade em comparação com choques negativos com a mesma magnitude. Especificamente para os resultados obtidos do modelo EGARCH, é possível perceber que o Alumínio e o Cobre obtiveram um coeficiente τ não estatisticamente diferente de 0, portanto, não existe assimetria na volatilidade, corroborando os resultados obtidos pelo modelo TARCH. As commodities Níquel e Zinco apresentaram um coeficiente τ estatisticamente diferente de 0 mostrando uma variância condicional assimétrica. Consequentemente, existe um impacto diferente por choques negativos e positivos na volatilidade. Finalmente, não foi verificado-se a existência do efeito alavancagem nas commodities.

Palavras chave:
Volatilidade, Preços, Metais não ferrosos.

1. Introduction
The non-ferrous metals production is currently a widely issue discussed in the literature, since it is commodity class that can contribute positively to the Gross Development Production of a given country, by generating employment and income opportunities. In this way, studies that analyze the Aluminum, Copper, Nickel and Zinc behavior in terms of price variation, has a notable relevance (1, 2, 3).

In this context, a non-ferrous metals price analysis it’s crucial. This is not merely to the fact that Aluminum, Copper, Nickel and Zinc is a source with a high commercial value, but also because maladjustment in consumption and production levels can generate troubles in prices. Cyclic and / or seasonal fluctuations can severely compromise the industry and workers, as well as export levels. Thus, comprehend the volatility pattern fluctuation of these prices can help in the policies implementation to stabilize the growing of emerging and exporting countries throughout the years (4, 5, 6, 18).

This paper aims to analyze the aluminum, copper, nickel and zinc volatility returns in the period from 1980 to 2017. Specifically intends to: a) analyze the afore mentioned non-ferrous
metals conditional volatility price; b) identify the reaction, persistence and leverage effect mechanism against shocks; and c) infer possible risks for exporters countries as Brazil.

There are in the literature some studies that deal with this subject. As examples, we can mention the works of (7, 4, 8). The present study differs from these others, since it presents a volatility study to a large group of non-ferrous metals since this kind of research it is not frequent in the first Brazilian. The local development of ARCH, GARCH, TARCH and EGARCH studies it is crucial in the context of an emerging miner country as Brazil.

2. Material and Methods

The secondary data adopted measure up to the Aluminum, Copper, Nickel and Zinc average monthly prices. The series drift from the international market and was obtained from the International Monetary Fund (9), due to its reliability and to use the main international trade route of each commodity under study. Prices were deflated in relation to US inflation, using the Producer Price Index (PPI) - Primary nonferrous metals series of the Bureau Labor Service (10). The observations cover the period from December 1980 to April 2017, making a total of 436 months.

Figure 1 presents the histogram and kernel density distributions of each analyzed commodity. It is possible to see that the density function differs from the Gaussian distribution ones. According to that and the financial theory, this paper modeled the normalized returns of each commodity at time \( t \), then the variation between the moment \( t - 1 \) and \( t \) is given by \( P_t = P_t - P_{t-1} \). Denoting \( P_t = \log_e(P_t) \). The return is defined by \( r_t = \left[ \log_e(P_t) - \log_e(P_{t-1}) \right] \), it takes the logarithm of prices, then the first difference (11).

According to the Aluminum, Copper, Nickel and Zinc prices, this paper will identify the price behavior pattern in terms of its returns. For this, it is intended to observe the presence of prediction errors on the prices, as well as verify heterocedastic patterns in their returns. The heterocedastic pattern may indicate instability and uncertainty in the financial market due to changes in the government's economic policies and in the exchange relations between countries (12).

Complementarily, this paper utilizes the GARCH model aiming to verify the volatility persistence and complementary, determine the presence of asymmetric volatility according to the class TARCH and verify the presence of leverage effect using the EGARCH models.
3. Results and Discussion

According to the analyzed period, Figure 2 shows the price and return series behaviour for Aluminum, Copper, Nickel and Zinc. A visual analyze indicates also some periods with low and high volatility for the series return, signalizing in this way a dependence relation of this series in relation to its lagged periods.

After the historical analysis, it is important to proceed an unit root test. The Table 1 (Appendix) indicates stationary in the first difference to Aluminum, Copper, Nickel and Zinc prices. The results were statistically significant for all commodities at a significance level equals to p < 0.01. In parallel, unit root models incorporating the effect of constant and trend were also elaborated, reaching similar values those presented in Table 2 (Appendix).

From the unit root test, as well as the sample and partial correlograms analysis, an ARIMA model (p, d, q) was adjusted for the returns series to correct the existing correlation in the errors. The correlogram analysis indicates the presence of autoregressive vectors: Aluminum: AR (order 3), Moving Average (order 3); Copper: AR (order 1 and 2), Moving Average (order 1); Nickel: AR (order 1); Zinc: AR (order 1). The truncation process, through the covariance matrix, was applied to the model, thus correcting the autocorrelation and heteroscedasticity problem (13).

In order to detect the possibility of non-constant variance in the model errors, the heteroskedasticity test with ARCH standard was performed. Table 3 shows the results of the probabilistic values related to the null hypothesis (homoscedasticity presence in the returns)
which was rejected. Especially to detect the serial autocorrelation problem, (14, 15, 16, 17), LM test was made. The results shown in Table 3 indicate the serial autocorrelation presence.

In order to adjust a model that corrects the autoregressive conditional heteroscedasticity processes, Table 2 (Appendix) presents an “ex-post” analysis, presenting the associated results to each resid estimated. It is possible to see that the null hypothesis (homoscedasticity presence in the returns of Aluminum, Copper, Nickel and Zinc) were satisfied.

With the objective of estimating a model that visualizes the volatility component in the return series, a selection of GARCH, TARCH and EGARCH models was performed by comparing the Akaike (AIC), Schwarz (SBC) and Logarithmic Likelihood indicators, in order to obtain Table 3 presents the model that best describes the volatility component of each commodity.

The necessary condition for positive variance and weakly stationary implies that the regression parameters are greater than zero. Thus, the parameter represented by the ARCH is the reaction of volatility and the parameter represented by the GARCH, the last parameter, is the persistence of volatility. The sum ARCH and GARCH coefficients determine the risks persistence in the returns. For the Aluminum this value was 0.9687, followed by Copper with a value equals to 0.9252. The volatility reaction it is 0.9834 to the Nickel and 0.9707 to the Zinc. The aforementioned results indicates that the volatility persistence it is forceful trailed by shocks on prices. This means that the analyzed non-ferrous metals are highly susceptible to shocks caused by price changes, which emphasizes the need of a robust economic planning to the main exporting countries. It is perceived that the values are similar, however the Nickel is the most susceptible to volatility shocks.
According to TARCH (1,1) results presented by Table 6, it is possible to see that the $\gamma$ coefficient it is not statistically different from 0 (zero) and the conditional variance it is not asymmetric to Aluminum and Copper. As it is possible to verify $\gamma$ it is statistically different from 0 (zero) to Nickel and Zinc, so, they have an asymmetric conditional variance. Nickel has a value equals to -0.1340, that it, $\gamma < 0$, so, a positive shock on prices implies in a lower volatility in comparison with negative shocks with same magnitude. In this way, positive shocks that affect prices will have an impact equals to 0.2383, however negative shocks will impact 0.1043 on the Nickel prices. The Zinc, on the other hand, presents a coefficient equals to -0.0826, therefore, $\gamma < 0$, so a positive shock on prices implies in a lower volatility in comparison with negative shocks with same magnitude. In this way, positive shocks that affect prices will have an impact equals to 0.1059, however negative shocks will impact 0.023 on the Zinc prices.

Specifically to the EGARCH (1,1) model, evidenced in Table 6 it possible to perceive that the Aluminum and Copper had a $\gamma$ coefficient not statistically different from 0 (zero). Ergo, is does not exist asymmetry in volatility, corroborating the obtained results by the TARCH (1,1) model. The Nickel and Zinc commodities presented a $\gamma$ coefficient statistically different from 0 (zero), showing an asymmetric conditional variance. Accordingly, exists a different impact um by negative and positive shocks on volatility. Nickel has a $\gamma$ coefficient equals to 0.1049 and Zinc a positive coefficient equals to 0.0529, so it is not possible to verify the leverage effect.
4. Conclusion

The presented results are particularly important for exporting countries, since the non-ferrous minerals contribute to the Gross Domestic Product (GDP), as well as the employment level for different countries. In this context analyzing the serial prices behavior of Aluminum, Copper, Nickel and Zinc is of fundamental economic importance, since large oscillations increase the uncertainty degree of economic agents and financial losses. In this way, volatility analysis is a risk minimizing mechanism of fundamental importance. In order to capture the conditional volatility terms and identify its reaction mechanism and persistence against shocks, the volatility asymmetry and the leverage effect it was estimated the GARCH, TARCH and EGARCH models for the aforementioned commodities return series, which was characterized by the process of autoregressive conditional heteroscedasticity.

The sum of the reaction coefficients (ARCH) with the volatility persistence coefficient (GARCH), which defines whether the risks persist in the series of returns, resulted in values close to 1.0 to all the commodities, indicating that volatility shocks in prices will last for a long time. This means that changes in the non-ferrous metals production represent high uncertainty.

Therefore, the volatility and price reaction in the face of positive and negative supply and demand shocks are important parameters for the decision making in the public policies and private investments formulation in the industry. Protecting producers and agents involved in the supply chain is extremely important in emerging countries, because this sector it is an important part of the economy.

According to TARCH results it is possible to see that the conditional variance it is not asymmetric to Aluminum and Copper. As it is possible to verify γ it is statistically different from 0 to Nickel and Zinc, so, they have an asymmetric conditional variance. Positive shocks in Nickel and Zinc prices imply a lower volatility in comparison with negative shocks with same magnitude. Specifically to the EGARCH obtained results it possible to perceive that the Aluminum and Copper had a γ coefficient not statistically different from 0, so is does not exist asymmetry in volatility, corroborating the obtained results by the TARCH model. The Nickel and Zinc commodities presented a γ coefficient statistically different from 0 showing an asymmetric conditional variance. Accordingly, exists a different impact um by negative and positive shocks on volatility. Finally, it was not possible to verify the leverage effect in the analyzed commodities.

5. References


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## Appendix

### Table 1. Augmented Dickey-Fuller test (ADF) to the analyzed commodities

<table>
<thead>
<tr>
<th>ADF Test</th>
<th>Level</th>
<th>Aluminum</th>
<th>Copper</th>
<th>Nickel</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>t-Statistic</td>
<td>Level</td>
<td>-0.737/476</td>
<td>0.004924</td>
<td>-1.217618</td>
<td>-0.221484</td>
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<tr>
<td>1% level</td>
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<td>-2.570289</td>
<td>-2.570289</td>
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</tr>
<tr>
<td>5% level</td>
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<td>-1.941553</td>
<td>-1.941553</td>
<td>-1.941553</td>
<td></td>
</tr>
<tr>
<td>10% level</td>
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<td>-1.616211</td>
<td>-1.616211</td>
<td>-1.616211</td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. ARCH test to homoscedasticity and Serial autocorrelation test

#### Ex-ante analysis (analyzing the returns of each commodity)

<table>
<thead>
<tr>
<th>Lags</th>
<th>Aluminum</th>
<th>Copper</th>
<th>Nickel</th>
<th>Zinc</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0000</td>
<td>0.0005</td>
<td>0.2757</td>
<td>0.0332</td>
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<tr>
<td>5</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0978</td>
<td>0.0076</td>
</tr>
<tr>
<td>10</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.1388</td>
<td>0.0007</td>
</tr>
</tbody>
</table>

#### Serial autocorrelation test: Breusch & Godfrey (1981)

<table>
<thead>
<tr>
<th>Lag</th>
<th>Aluminum</th>
<th>Copper</th>
<th>Nickel</th>
<th>Zinc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.7209</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0000</td>
</tr>
<tr>
<td>5</td>
<td>0.4716</td>
<td>0.0000</td>
<td>0.0000</td>
<td>0.0023</td>
</tr>
<tr>
<td>10</td>
<td>0.4432</td>
<td>0.0000</td>
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<td>0.0063</td>
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</table>

#### Ex-post analysis (analyzing the persistence of heteroskedacity in residuals)

<table>
<thead>
<tr>
<th>Model - Considering Lag 1</th>
<th>Heteroskedasticity Test ARCH: Engle (1982)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>P-Value</td>
</tr>
<tr>
<td>GARCH (1,1)</td>
<td>0.7958                      0.9416                      0.2831                      0.2581</td>
</tr>
<tr>
<td>TARCH (1,1)</td>
<td>0.8573                      0.8511                      0.2407                      0.2776</td>
</tr>
<tr>
<td>EGARCH (1,1)</td>
<td>0.6298                      0.8952                      0.2461                      0.2710</td>
</tr>
</tbody>
</table>