Assessment of the economic impact of product certification: A significant area of application of measurement

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Abstract

Measurements to test whether the application of national and international standards and harmonized metrology-related procedures have impact on trade were carried out. The economics of conformity assessment procedures and their impact on trade of industrial products were reviewed. In particularly, the associated economic impact resulted from product certification induced by technological and macroeconomic variables was assessed. Within the context of a case study, four key leading industrial products (steel, bus coachwork, automotive tires and cement) exhibiting potential export were investigated. With the exception of cement, whose production is nearly matched by consumption, the other three possess growing export potential. The production time series of these products were fitted by means of a multiple linear regression method, successfully applied to a 5% level of significance. For all products studied, a substantial growth in production (over 11%) was attributed to product certification; translating into a significant economic impact. The multiple linear regression approach was able to account for the idiosyncrasies of shared product standards and conformity assessment procedures in specific industries to explain an increase in production which, directly, affects trade.

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Keywords: Measurement of economic impact; Product certification; Metrology; Industrial products; Multiple linear regression

1. Introduction

With the onset of globalization, macroeconomic reforms were implemented worldwide. These reforms sponsored by Bretton Woods Institutions were put into practice in Latin America. And a surge in the region’s international trade favoured by an increase of global demand of their major products (fuels, metals and primary products) [1] made local policy makers believe that the systematic application of the new liberal agenda would bring about a new era of prosperity. But scant investments in basic infrastructure which would include an integrated network of MSTQ services (metrology, standards, technical regulations, accreditation and different forms of conformity assessment) arrested development.

Technologically speaking, some nations were already better equipped than others to face the
challenges imposed by the IMF’s structural adjustment programmes. And just a few implemented a sound MSTQ system; a shrewd strategy to build up a strong industrial base. Although difficult to measure, a correlation does exist between the two. In general, it seems reasonable to say that the more industrialized the nation the more robust is its MSTQ infrastructure. In other words, MSTQ plays an strategic role in economic development.

Seen as an essential element to meet the tight requirements of a fast-growing world trade, an integrated MSTQ system has attracted the attention of local governments and the private sector. Furthermore, the voluntary nature of international standards – one of the MSTQ functions – which reduces transactions costs, fosters competitiveness and facilitates business through the trade goal “tested once accepted everywhere” may play a significant role in the region’s economic growth.

In the 1990s, the world’s economy has witnessed an increase in volume of cross-border transactions in goods and services. Markets have become global in scope and encompassed a greater range of goods and services. And financial markets around the world are now connected through instant computer link-up. No matter how enthusiastically welcome by some or strongly criticized by others, globalization is here to stay. According to a UN report [2] ‘‘...globalization has set in motion a process of deep changes with far-reaching consequences that is affecting everyone’’. New technologies have created an interdependent and interconnected world never seen before in human history.

In Latin America, globalization has generated mixed feelings. In one hand, it sparked off democratic regimes in the region but on the other, it brought uncomfortable economic instabilities. The painful adjustments of the 1990s proclaimed by pro-market economic doctrines [3] and the inability of many Latin American governments to implement a sound and internationally recognized MSTQ system to support industrial development have yet to deliver the desirable economic and social results. Regrettably, income inequality has increased throughout the region.

To the economic volatility of global markets and the aggressiveness of global traders, the South Cone (Argentina, Brazil, Paraguay and Uruguay) responded with regional integration mirrored in the European Community (EC). The Mercosur – a regional common market created in 1990 – was meant to be a free trade zone to gain economic scale and enjoy comparative advantages (essentially the complementary character of the Brazil’s and Argentina’s economies) among its member states. Nonetheless, integration within Mercosur, does not seem to be delivering on its promises.

According to Averburg [4], due to protectionism (heavy agriculture subsidies, undesirable protectionism policies and asymmetry of national standards not yet harmonized through regional standards) exports from Mercosur to the EC increased by only 25% while imports skyrocketed to 274% between 1992 and 1996. Among other reasons, this certainly reflects vulnerability or lack of harmonization of their MSTQ system as products tested by exporters must be accepted by importers. Asymmetries in conformity assessment procedures usually lead to costly duplication of product testing and recertification.

A rebound in its economic activities has led South America’s trade to recover vigorously in 2004. Real imports expanded nowhere else faster than in this region. However, a number of economies in Central America and the Caribbean did not participate in this remarkable trade expansion. According to the 2005 WTO Report [5]. While the world economy grew at a rate of 4% in 2004 – the strongest annual rate in more than a decade –, South American countries were among the most dynamic traders in 2004, period in which the region exhibited a 9% growth in its foreign trade – the best performance since 2000. Real imports in South America grew by 18.5%, which was twice as fast as that of the world trade. Argentina’s imports recovered dramatically (by an increase of at least 50%), while Brazil’s and Chile’s expanded by 20%. In line with the prevailing post-war pattern, trade growth outstripped GDP growth in the region by a significant margin of 5% points. These figures confirm that nowadays, global GDP are more broadly based regionally than in the preceding years providing a solid basis for acceleration in trade growth. If this pattern continues, trade will become an ever more crucial component of global economic activity.

Government and Industry rely upon the results of measurements (calibration and testing) and certification in almost all aspects of daily life in contemporary society. Considered as essential services, these measurement related activities are crucial in today’s world and no longer a “hidden” part of national technical infrastructures. Governments depend and use measurement and certification for
enforcement of or compliance with regulations, export/import controls, consumer protection, health/safety management, protection of the environment, forensic investigations and Government purchasing. Industry uses them for quality assurance of goods and services, quality control in manufacturing, risk assessment and risk management, compliance with regulations, failure investigations, resolutions of disputes and complaints and even for advertising data. In this context, product certification guarantees consistency of manufacturing products in accordance with their technical specification. Not only does product certification guarantee that different parts of a product fit together and meet design requirements regarding its performance but it also ensures that measurements carried out worldwide can be relied upon. Furthermore, internationally recognized product certification leads to the trade approach “tested once accepted everywhere”, allowing products to circulate freely across borders. In this sense, product certification is in fact a crucial area of application of measurement. An exclusive conformity assessment service, which provides an economical and cost-effective way to “measure” quality of goods and product safety design and testing.

The aim of this work is to measure the effect of application of internationally harmonized standards and conformity assessment procedures to enhance production and, therefore, to promote trade. Specifically, by means of an econometric model, the work assess the combined effect caused by (i) product certification, implemented based on international standards and best practices; (ii) the presence of the regional economic environment; (iii) the exposure of the market to international trade competition; and (iv) the undesirable financial inflation experienced in the period.

2. Basic MSTQ infrastructure for product certification

In today’s domestic and international trading environments, all countries need access to basic MSTQ services, to enhance quality and competitiveness, facilitating the entry of their products in strongly competitive markets.

Appendix I describes the basic elements of a multi-functional MSTQ system recognized by the WTO – a major requirement for enforcement of technical regulation and effective implementation of compulsory and voluntary conformity assessment. Product certification based on international standards was taken as an example as it reflects the main objective of this work.

As the technological basis of a streamlined regulatory framework, a well functioning MSTQ system is required to ensure uniformity, reliability and recognition of measurements performed by domestic laboratories and of testing and inspections conducted by conformity assessment bodies and regulators. An MSTQ system guarantees that products which comply with standards and technical specifications do meet quality expectations of consumers and are not detrimental to health and to the environment.

Fig. 1 illustrates the fundamentals associated with product certification, a formal conformity assessment process underpinned by four essential major infrastructures which require international recognition and access (i) to measurement capability; (ii) to documentary voluntary standards; (iii) to mandatory legislation applied to the regulated sectors (technical regulation) and (iv) to a formal system of trust capable to assess the competence of the providers of conformity assessment services; i.e., to establish formal recognition that providers of these services are both technically competent and operate within the disciplines of international standards and best practices. International recognition is then ensured through effective participation in international activities and/or access to complex systems of mutual recognition arrangements (MRAs). Among these, one underline the international organizations dealing with fundamental metrology (BIPM), technical regulation (WTO), legal metrology (OIML), accreditation of laboratories (ILAC) and of certifying bodies (IAF) including those standard bodies responsible for the development, adoption and application of international standards (ISO and IEC).

Fig. 1 depicts a typical example of certification used to attest the quality of products, facilitating their access to external markets. This figure also shows the underpinning services (metrology, standards, technical regulation and accreditation) required to ensure international recognition. And these are the basic elements which encompass a sound integrated MSTQ system understood as an inherent part of the basic industrial technology infrastructure of any trade partner willing to compete in competitive markets.

This is the system which might be put in place in order to operate in full compliance with interna-
tional standards and best practices to support and to meet an ever increasing demand for calibration, accreditation, voluntary and compulsory conformity assessment services needed to support product certification.

The present study reflects just one of many examples of economic benefits resulting from an adequate use of metrology and other MSTQ related functions which cannot be straightforwardly quantifiable. But there are also examples of risks created by the misuse of MSTQ functions and the penalties for not using them at all.

3. Asymmetry of information

In early studies, Akerlof [6], Spence [7] and Rothschild and Stiglitz [8] set up the governing principles of modern information economics. For their relevant individual contributions to this field they were awarded the Nobel Prize for economics, in 2001. Their remarkable work drastically modified the way economists perceived the functioning of the market and explained how information asymmetries affected the rationale of social and economic institutions. Since then, other researchers [9–12] have used and extended their original ideas to confirm that information asymmetry does hinder market efficiency. In Stiglitz’s own words “lack of knowledge of products of good quality in a given market may lead to their exclusion by unfaith competition between producers; i.e., societal inefficiency to asymmetric information flows”.

Asymmetry of information naturally leads to:

- **Adverse selection**: a term used in economics and insurance to refer to a market process in which bad results occur due to information asymmetries between buyers and sellers. As a result, “bad” products may be selected or uninformed customers may be deceived and

- **Moral hazard**: opportunism characterized by an informed person who takes advantage of a less-informed one, through an unobserved action (example: employee shirks if not monitored by
employer) that, in turn, may induce to market failure or market exclusion of goods and services of higher quality.

Information asymmetries undoubtedly affect the efficient functioning of the markets, often leading to a supply of low quality product variety.

In the context of the present study, the authors will treat international standards and harmonized conformity assessment procedures applied to product certification as an effective tool which, in fact, reduces asymmetry of information between trade partners, therefore encouraging business and international trade.

3.1. The economics of standards to international trade

As quoted in the 2005 WTO report Exploring the links between trade, standards and the WTO \[5\], “...we live in a world profoundly reliant on product standards. They affect our lives in ways we sometimes do not even notice, but they can have far-reaching implications for economic activity, including trade”. In this respect, differences in regulation and national standards from country to country can act as no desirable barriers to trade, thus hindering commercial transactions. Generally speaking, the regulatory system of any country is comprehensive and inherently complex involving long (dynamic) lists of a products and services subject to specific legislation and mandatory and voluntary conformity assessment procedures. Because the responsibilities are usually spread and diffused under the control of different Ministries and regulatory agencies, the official asset of regulatory information is not always immediately available to domestic and international traders in a harmonized fashion.

As a result, asymmetry in the perception sensed by the different parties affects the regulatory system. In this context, lack of harmonization of standards and drastic changes in trade legislations may be perceived as asymmetries in the regulatory information system. And, in this context, standardization, quality and product certifications, constitute effective strategies to reduce asymmetry of information between sellers and buyers.

Standards – considered the minimum acceptable criteria to be met – are the cornerstone of compliance and the technical rules for ensuring quality of products and product safety design and testing. When a product conforms to the relevant standards, a presumption of conformity does exist otherwise they were not referred to. A good example is the broad and complex area covered by safety standards (safety requirements).

Examples of how standards affect our world today abound in the literature. Safety technical regulations allow citizens to consume products with confidence that otherwise would be impossible if they were to make their own judgments about safety in everyday life at every turn. Rules of conduct and product standards in several areas of the industrial activity help consumers to avoid inefficiency, unpleasant surprises, and high transaction costs.

Safety, higher quality products, technological innovations, the expansion of commerce, social issues and the environment have boosted, in recent years, standardization activities. By the end of 2004, a consortium of European standards organizations (Perinorm) had recorded about 650,000 standards (national, regional and international) from 21 countries. Since its foundation in 1947, the International Organization for Standardization (ISO) has developed around 14,900 international standards. More recently, non-governmental organizations (NGOs) have also been involved in standard-setting, essentially related to the environment and corporate social responsibility \[5\].

Although local standards (as opposed to the application of international standards) may have the effect of protecting local producers against foreign competition (though domestic producers may be interested in maintaining this protection) reduction of asymmetries certainly diminishes transaction costs and facilitates international trade. Yet harmonization to international standards is a double-edged sward: in one hand, it reduces product variety, but on the other, it ensures technical compatibility across countries. This reduces information asymmetry between manufacturers and consumers about products that have been manufactured abroad or processes that took place in another country.

Standards can also increase welfare of citizens by removing information asymmetries in markets. Information asymmetries that occur when producers have information about the characteristics of goods they produce which users do not possess. As end consumers or as firms, buyers may be at a significant disadvantage compared to sellers because the latter possess information about the good or service not available to the first. This asymmetry may significantly hamper the efficient functioning of markets. The use of harmonized standards and
product certification may help to circumvent it. Product safety through product certification is a fertile soil in which standards may drastically reduce information asymmetry. From design (e.g. toys), to ingredients (e.g. chemicals); from manufacturing (e.g. pasteurisation of milk) to performance (e.g. helmets), a wide range of consumer goods – food, drugs, vehicles, electrical appliances, safety equipment – meet different types of requirements. In the health sector, the economic cost from accidental injuries and deaths may be large. For instance, in 2003, in the United States alone, there were more than 12 million accidents related to inadequate products which led injured people to be treated in hospitals. The US Consumer Product Safety Commission estimates that the economic costs of these accidental deaths and injuries would be about USD 700 billion annually [5]. The potential gains resulting from adequate use of safety standards and of conformity assessment procedures are unmistakably relevant.

3.2. Certification: an internationally recognized tool for reducing information asymmetry

Systematic applications of harmonized standards to international trade (asymmetry reduction) over the last decades have helped to bring down tariffs worldwide. When a product, a service or process has, or can be given, uniform certification, transactions are made much easier because economic agents know what they are buying and selling. As a result, expanding markets for goods and services provide new outlets for developing countries wishful to benefit from globalization. But access of developing countries products to developed countries markets is often hampered by differences in regulations as observed by Gracia and Bañados [13]. As already defined, certification is a written assurance (the certificate), understood as a formal procedure by which a third-party guarantees that the system, process, product or service complies with the requirements of specified standards or technical regulations.

Both producers and consumers may perceive certification as a procedure that restores transparency in imperfect (or faulty) markets in situation where information is not equally shared. In the presence of information asymmetries, quality certification becomes essential to protect producers who want to be assured that the products they are selling comply with specified technical standards and (specially) consumers who want to be convinced of the quality of the products they are buying. As a result, certification enhances the efficient functioning of markets. Certification can also be understood as a reference for quality by means of a third-party independent body acting as a guarantor – by technical expertise and by instrument of test and control – of the products that are being certified.

Based on abundant theoretical and empirical evidence Nicolau and Sellers [14] suggested that a market reacts positively when certification is granted to a product or service. Their results strongly support the claim that quality and product certification employed by companies substantially reduces asymmetry in the information available to companies and consumers.

4. Modelling

The effect of product certification on the production of goods exhibiting potential export was investigated by means of an econometric tool. While “product certification” (understood as a variable of technological nature) is modelled as a dummy variable, “production” and “monetary inflation” are treated as time-series macroeconomic variables. Two other macroeconomic variables (dummy) were also taken into consideration in the analysis to account, respectively, for the exposure of the studied products to regional and international markets.

Among several methods available in the literature [15,16] to model linear relationships between a dependent variable (predictand) and independent variables (predictors), the multiple linear regression method (MLR) was selected. It reflects a variation of the classical least square technique that minimizes the sum-of-squares of differences of observed and predicted values. In the process of fitting the variables, statistics are compiled to validate the method at a confidence level of 95%. This is the probability that ensures, in all cases, a p-value of less than 0.01 (99%) in order to confirm the quality of the results. Preliminary tests confirmed linear correlation between variables therefore guaranteeing application of the method. Appendix II describes the relevant statistical parameters.

4.1. Case study

Definition of a case study to support an investigation on measurement of economic impact such
as this involves at least the following basic ingredients: (i) regional trade agreement market, (ii) country macroeconomic information on market access, (iii) reliable official data on time series of production of goods, (iv) criteria for selecting products and (v) basic information on the national MSTQ infrastructure.

Mercosur (effectively implemented in 1995) provides an attractive free regional trade area to study the economic impact of product certification. Given the importance of regional trade to the economy of the block as a whole, Mercosur is in process of consolidation through a combination of technical advances, deregulation and liberalization, giving rise to keen competition among suppliers. Among Mercosur members, Brazil was chosen for the following reasons: (a) availability of reliable production time series and certification data of industrial products through different government agencies; (b) the fact that country experienced a drastic macroeconomic reform implemented in the 1990s leading to a more competitive market economy; (c) access to international mutual recognition agreements which ensures credibility of its measurement capability (BIPM MRA) and of its accreditation schemes (ILAC and IAF MRA), pre-conditions for product certification. Once the regional market and country have been chosen, the industrial products were selected based on their potential export (ranked with respect to world production); impact on trade balance; type of applicable certification, of the voluntary or compulsory nature (Table 1 lists the industrial products selected and their relevant attributes).

4.2. Governing equations

The governing equation (that relates the value of a predictand variable as a linear function of the predictor variables and an error term) may be written as follows:

\[ Y_T = \beta_0 + \beta_1 X_{1,T} + \beta_2 X_{2,T} + \cdots + \beta_K X_{K_T} + u_T \]  \hspace{1cm} (1)

where \( Y_T \) is a time-dependent variable vector, \( X_{T,1:K} \) are values of the \( K \)th term of the independent variable \( T \) (expressed in months), which assume values 1 or 0 (dummy variables), \( \beta_0 \) is the regression constant, \( \beta_{1:K} \) are coefficients of the \( k \)th independent variable, \( K \) is the total number of independent variables, \( u_T \) is a time-dependent error term vector and \( \beta_{0:K} \) are estimated values.

When applied to the four industrial products studied, Eq. (1) becomes

\[ Y_T = \beta_0 + \beta_1 X_1 + \cdots + \beta_{K-1} X_{K-1} + \beta_K X_K + u \]  \hspace{1cm} (2)

and the final regression equation, which fits the model, is given by the average production \( \bar{Y} \) for the estimated period:

\[ \bar{Y}_T = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \cdots + \hat{\beta}_K X_K + u \]  \hspace{1cm} (3)

where \( \bar{X} \) are the average of the predictors and \( \hat{\beta}_{1:K} \) are the linear regression coefficients.

4.3. Dummy variables and time series

To assess the economic impact of the combined effects (certification and macroeconomic variables) on the production of the selected products (cement, steel, automotive tires and bus coachwork), by means of the multiple linear regression method, three dummy variables were introduced in the model.

These dummy variables characterize the periods that preceded and followed specific events:

- the introduction in Brazil of product certification for the four manufactured goods (August/1994, for cement; January/1997, for steel; January/1993, for bus coachwork and May/1996, for automotive tires);
- the date (January/1995) when the Mercosur trade agreement came into effect;
- the date (January/1990) when the macroeconomic reforms begin to be implemented in the country (transition to a more competitive market economy);
- the effect of the monetary inflation in the period.

<table>
<thead>
<tr>
<th>Table 1</th>
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<tbody>
<tr>
<td>Relevant data of the selected products</td>
</tr>
<tr>
<td>Production</td>
</tr>
<tr>
<td>Cement&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Steel&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Automotive tires&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Bus coachwork&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>b</sup> ANIP (www.anip.com.br/2004).
<sup>c</sup> ANFAVEA (www.ufavea.com.br, 2004).
<sup>d</sup> Bus coachwork is also known as bus body or bus shell.
The production time series of the products investigated were made available by the Brazilian Institute of Economic and Planning (IPEA), an agency of the Ministry of Planning, Budget and Management.

The following time intervals were used as input data:


Due to its inherent nature, the causal variables under consideration are classified in two different categories. “Certification” is certainly a variable of technological nature introduced to infer quality while “the opening up of the market”, “Mercosur” and “monetary inflation” are external variables of macroeconomic nature.

“Certification” (CERT), “Mercosur” (MERC) and “the opening up of the Brazilian market” (APER) – not of numerical nature – were modelled as dummy variables and “production” (PROD) and “inflation” (INF) as time series.

The values 0 (zero) or 1 (one) were assigned to the dummy variables $X_T$ according to their status (absence or presence, respectively).

When $X_t = 0$ and $X_t = 1$ are applied to Eq. (2) one obtains:

$$Y_{X_T=0} - Y_{X_T=1} = \beta_{1,K}$$

where $K = 1, 2$ and 3 stand for the variables CERT, APER and MERC.

The coefficients $\beta_1$, $\beta_2$ and $\beta_3$ for each one of the four products can then be obtained from Eq. (4) solved for each one of the dummy variables.

5. Results and discussion

The production time series together with the input dummy variables considered were processed by the multiple linear regression method yielding the sensitive polynomial coefficients defined in Eq. (1). The final results are given in the blocks below, organized by products studied.

Based on these sensitive coefficients, calculated by the multiple linear regression technique, Eq. (3), which applies to all products, is rewritten in the form

$$\text{PROD}(Y) = C(1) + C(2) \times \text{CERT} + C(3) \times \text{APER} + C(4) \times \text{MERC} + C(5) \times (-\text{INF}) + C(6) \times \text{RESID01}(-1)$$

5.1. Multi linear regression: combined effect on production

The four boxes (Box 1–4) presented below summarizes information on product certification, the corresponding applicable standards, the MLR polynomial equation, and graphics data output of actual and fitted time series (scattered in a monthly basis), for each of the four products. These boxes (displayed in the software standard format) also include all relevant statistics generated by the multiple linear regression technique, the influence coefficients and the probabilities of model adequacy. Production under certification is indicated on the right side of the vertical dotted line shown in these figures. For the sake of comprehensiveness, relevant concepts and definitions associated to the statistics referred in this work are given in Appendix III.

5.2. Impact on production

As can be observed, certification promoted an increase in production. From the results obtained by the linear regression, it is even possible to build indicators of quality and productivity inspired in international references. In this context, certification plays a key role in the standardization of production, forcing industry to comply with common protocols. And, in so doing, it reduces asymmetries of information to bring down barriers to trade and to protect consumers against unfair competition among producers.

Summary of the overall multi linear regression data (presented in the four blocks above) are shown in Table 2.

The $\beta_{1,K}$’s sensitive coefficients reveal the impact of each variable on production of the four manufactured goods. For example, if one considers the exposure of the Brazilian market to international competition (APER), the impact on the production of bus coachwork (34.3%) is much greater than that on the production of cement (6%). An impact that reflects the greater export potential of the bus coachwork over cement whose national production
is entirely (99.4%) consumed by the domestic market. Now, if one focus on a specific product, for example steel, the impact is 14.9% due to the variable “the opening up of the market” (APER); 12% to certification; 8.9% to Mercosur and 3.0% to inflation.

As an overall result, the impact of these variables on the industrial production (the dependent variable also modelled as time series) confirmed the evidence (95% probability) of the existence of a causality

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As an overall result, the impact of these variables on the industrial production (the dependent variable also modelled as time series) confirmed the evidence (95% probability) of the existence of a causality
effect between this production and the variables studied.

Box 3. Product: Automotive tires

Type of certification: Mandatory (implemented in May/1996)
Applicable standard: INMETRO (Resolution, of Dec. 27,96)
MLR Equation: \( PROD = 85.36367744 + 13.27356515 \times CERT + 14.0935307 \times APER + 7.23907449 \times MERC + 0.304128258 \times (-INF) + 0.717058231 \times RESID1(-1) + 0.4261585896 \times RESID2(-12) + 0.3162784034 \times RESID2(-24) \)

Automotive tires: actual and calculated time-series data.

Automotive tires: regression data
Dependent variable: production of tires
Method: least squares
Date: 01/25/05 Time: 17:46
Sample (adjusted): 1978:01 2004:01
Included observations: 313 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
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<tr>
<td>C</td>
<td>85.36368</td>
<td>0.811451</td>
<td>105.1989</td>
<td>0.0000</td>
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<td>CERT</td>
<td>13.27357</td>
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<td>6.097363</td>
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<td>APER</td>
<td>14.09353</td>
<td>1.330753</td>
<td>10.59064</td>
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<td>MERC</td>
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<td>0.042522</td>
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<tr>
<td>RESID1(-1)</td>
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<td>21.54817</td>
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<tr>
<td>RESID2(-24)</td>
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<td>R-squared</td>
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<td>Mean dependent var 102.8824</td>
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<td>Adjusted R-squared</td>
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<td>Mean dependent var 102.8824</td>
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<td>Schwarz criterion</td>
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<td>F-statistic</td>
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<td>Durbin–Watson stat</td>
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<td>Prob(F-statistic)</td>
<td>0.000000</td>
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<tr>
<td>Durbin–Watson stat</td>
<td>2.091419</td>
<td>Prob(F-statistic)</td>
<td>0.000000</td>
<td></td>
</tr>
</tbody>
</table>

Box 4. Product: Coachwork bus

Type of certification: Mandatory (implemented in Jan/1993)
Applicable standard: Government Resolution INMETRO nº 109 and subsequently updated in 1992 no. 19 and 49
MLR Equation: \( PROD = 898.5417859 + 332.9432012 \times CERT + 858.2414414 \times APER + 418.7980387 \times MERC + 5.939085625 \times (-INF) + 0.6376881205 \times RESID01(-1) + 0.443961749 \times RESID02(-12) \)

Coachwork bus: actual and calculated time-series data.

Coachwork bus: regression data
Dependent variable: bus shell
Method: least squares
Date: 05/12/05 Time: 12:15
Sample (adjusted): 1981:02 2004:10
Included observations: 285 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Standard error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>898.5418</td>
<td>41.21898</td>
<td>21.79922</td>
<td>0.0000</td>
</tr>
<tr>
<td>CERT</td>
<td>332.9432</td>
<td>92.79201</td>
<td>3.588059</td>
<td>0.0004</td>
</tr>
<tr>
<td>APER</td>
<td>858.2414</td>
<td>71.08214</td>
<td>12.07394</td>
<td>0.0000</td>
</tr>
<tr>
<td>MERC</td>
<td>418.7980</td>
<td>87.51952</td>
<td>4.785196</td>
<td>0.0000</td>
</tr>
<tr>
<td>-INF</td>
<td>-5.939086</td>
<td>1.910054</td>
<td>3.109381</td>
<td>0.0021</td>
</tr>
<tr>
<td>RESID01(-1)</td>
<td>0.637688</td>
<td>0.041391</td>
<td>15.40636</td>
<td>0.0000</td>
</tr>
<tr>
<td>RESID02(-12)</td>
<td>0.443962</td>
<td>0.054903</td>
<td>8.086327</td>
<td>0.0000</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.443962</td>
<td>0.054903</td>
<td>Mean dependent var 1463.049</td>
<td></td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.443962</td>
<td>0.054903</td>
<td>Mean dependent var 1463.049</td>
<td></td>
</tr>
<tr>
<td>S.E. of regression</td>
<td>333.7996</td>
<td>Akaike info criterion</td>
<td>14.48321</td>
<td></td>
</tr>
<tr>
<td>Sum squared resid</td>
<td>30975355</td>
<td>Schwarz criterion</td>
<td>14.57292</td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>-2056.858</td>
<td>F-statistic</td>
<td>132.1056</td>
<td></td>
</tr>
<tr>
<td>Durbin–Watson stat</td>
<td>2.014266</td>
<td>Prob(F-statistic)</td>
<td>0.000000</td>
<td></td>
</tr>
</tbody>
</table>

The consistency of the regression carried out for the time-series associated with the four products investigated was successfully tested based on the relevant statistics given in the box below.
5.3. Economic impact

Tables 3–5 quantify the economic impact of each dummy variable (certification, the opening up of the Brazilian market and the presence of Mercosur, respectively) for the four manufactured goods. The following highlights a few remarkable examples of the economic impact (based on market prices) induced by each one of the four variables on the manufactured goods. Each of the calculated sensitive polynomial coefficients reflects the correspondent surplus in production which can then be translated in economic impact.

- **Induced by certification:** Cement is the product which most benefited from certification (15.1%). Since certification was implemented (during a 10-year period) it is estimated that the accumulated impact is of the order of USD 11.6 billion, USD 116 millions alone in 2005. Table 3 quantifies the economic impact due to certification on each one of the four products studied. As expected, certification unquestionably impacts on production. By its very nature, certification—a technological control variable—does affect production in a rather uniform fashion (between 11% and 15% on all products) unlike the non-uniform effect caused by the other variables of purely macroeconomic nature.

- **Induced by the opening up of the Brazilian market:** Similar to the previous analysis, bus coachwork was the product most affected by the variable “the opening up of the Brazilian Market” (34.3%), representing, in a 16-year period, USD 11.1 billion, shown in Table 4. This corresponds

<table>
<thead>
<tr>
<th>Product</th>
<th>Period under consideration (after certification was implemented)</th>
<th>Cumulative production</th>
<th>Percentage of impact (%)</th>
<th>Production surplus (due to certification)</th>
<th>International market average price (11/2005) (USD)</th>
<th>Overall economic impact for the whole period (Billion USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>From August/94 to August/04</td>
<td>365.7 × 10^6 ton</td>
<td>15.1</td>
<td>55.2 × 10^6 ton</td>
<td>212/ton</td>
<td>11.6</td>
</tr>
<tr>
<td>Steel</td>
<td>From January/97 to September/04</td>
<td>214 × 10^6 ton</td>
<td>12</td>
<td>25.7 × 10^6 ton</td>
<td>395/ton</td>
<td>10.2</td>
</tr>
<tr>
<td>Automotive tires</td>
<td>From May/95 to January/04</td>
<td>1.1 × 10^6 ton</td>
<td>11</td>
<td>121 × 10^3 ton</td>
<td>1297/ton</td>
<td>0.16</td>
</tr>
<tr>
<td>Bus coachwork</td>
<td>From January/93 to October/04</td>
<td>319,491 units</td>
<td>13.3</td>
<td>42492.3 units</td>
<td>81.069/units</td>
<td>3.4</td>
</tr>
</tbody>
</table>

Note: Except for bus coachwork whose production is expressed in manufactured units, all other figures in this table are expressed in thousands of tons of the production, calculated in an average monthly basis.
to an economic impact of USD 813 millions in the 2005 production. In contrast with the effect of certification, this non-controlled macroeconomic variable affected different products in a different rate. The opening up of the Brazilian market to international competition exerts (i) almost no effect on cement, whose 94% of the national production is consumed at home and (ii) gives rise to the largest impact (34.3%) on the production of bus coachwork, a product whose 45% of the manufactured units are exported (Brazil ranks 2nd in the world production).

- **Induced by Mercosur**: Cement was also the product most affected by the Mercosur trade agreement (23.5%), representing, in a 10-year period, USD 17.6 billion, which, based on international prices, corresponded to an impact of about USD 176 millions in 2005. But affected automotive tires by a mere 6%. Table 5 quantifies the correspondent economic impact induced by this variable on all products studied. Considering that Mercosur (a variable of macroeconomic nature) is sensitive to competitiveness and that the reduction of tariffs does affect the expansion of markets (shown in Table 5) one cannot extend this analysis to the other countries of the region without previous verification.

- **Induced by the monetary inflation**: It is well known that inflation is detrimental to economic activity. The negative values of $\beta_4\text{INF}$ obtained in this work (Table 2) unequivocally confirmed the harmful effect of inflation. As it impinges on production at different rates and at different time intervals, its impact cannot be accounted for in a similar manner. That’s why “inflation” (like production) was treated in the econometric model as a time series and not as a dummy variable.

### Table 4
Economic impact induced by the opening up of the Brazilian market

<table>
<thead>
<tr>
<th>Product</th>
<th>Period under consideration (after exposure to international competition)</th>
<th>Cumulative production</th>
<th>Percentage of impact (%)</th>
<th>Production surplus</th>
<th>International market average price (11/2005) (USD)</th>
<th>Overall economic impact for the whole period (Billion USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>From January/90 to December/04</td>
<td>$481.3 \times 10^6$ ton</td>
<td>6</td>
<td>$28.9 \times 10^6$ ton</td>
<td>$212/ton$</td>
<td>6.1</td>
</tr>
<tr>
<td>Steel</td>
<td>From January/90 to December/04</td>
<td>$382.2 \times 10^6$ ton</td>
<td>14.9</td>
<td>$56.9 \times 10^6$ ton</td>
<td>$395/ton$</td>
<td>22.5</td>
</tr>
<tr>
<td>Automotive tires</td>
<td>From January/90 to December/04</td>
<td>$1.9 \times 10^6$ ton</td>
<td>11.6</td>
<td>$0.22 \times 10^6$ ton</td>
<td>$1297/ton$</td>
<td>0.28</td>
</tr>
<tr>
<td>Bus coachwork</td>
<td>From January/90 to December/04</td>
<td>400,954 units</td>
<td>34.3</td>
<td>137,527 units</td>
<td>$81,069/units$</td>
<td>11.1</td>
</tr>
</tbody>
</table>

### Table 5
Economic impact induced by the presence of Mercosur

<table>
<thead>
<tr>
<th>Product</th>
<th>Period under consideration (in the presence of Mercosur)</th>
<th>Cumulative production</th>
<th>Percent of impact (%)</th>
<th>Production surplus</th>
<th>International market average price (11/2005) (USD)</th>
<th>Overall economic impact for the whole period (Billion USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>From January/95 to December/04</td>
<td>$353.9 \times 10^6$ ton</td>
<td>23.5</td>
<td>$83.2 \times 10^6$ ton</td>
<td>$212/ton$</td>
<td>17.6</td>
</tr>
<tr>
<td>Steel</td>
<td>From January/95 to December/04</td>
<td>$264.3 \times 10^6$ ton</td>
<td>8.9</td>
<td>$23.5 \times 10^6$ ton</td>
<td>$395/ton$</td>
<td>9.3</td>
</tr>
<tr>
<td>Automotive tires</td>
<td>From January/95 to December/04</td>
<td>$1.3 \times 10^6$ ton</td>
<td>6</td>
<td>$0.08 \times 10^6$ ton</td>
<td>$1297/ton$</td>
<td>0.1</td>
</tr>
<tr>
<td>Bus coachwork</td>
<td>From January/95 to December/04</td>
<td>271,219 units</td>
<td>16.7</td>
<td>45,294 units</td>
<td>$81,069/units$</td>
<td>3.7</td>
</tr>
</tbody>
</table>

### Footnotes
Table 6 summarizes the economic impact at a glance.

6. Conclusions

Public awareness of the role played by national standards and by conformity assessment infrastructure to promote trade has increased with the advent of globalization. An ever growing need to quantify the importance of product certification in the world trade has led academics to build up mathematical models to assess and measure its economic impact. The econometric model used here proved to be a simple and effective analytical tool to account for the combined effect of technological and macroeconomic variables on the production of industrial manufactured goods. The results, validated by its 5% level of significance (probability value lower than 0.05), strongly suggested the existence of a cause-effect mechanism between production and the causal variables. With the exception of inflation, whose deleterious effect is well documented in the literature, all other variables induced an increase in production. Unlike the macroeconomic variables (inflation, regional and international market accesses) whose impact on products is uneven, certification exerts a rather uniform effect on production. This may be accounted for by the fact that a product certified is, in general, less sensitive to macroeconomic fluctuations.

In terms of financial gain, the economic impact is quite substantial. Based on international prices practiced in 2005 (taken as the reference year), the economic impact induced by the certification of steel (12%) represented USD 1.5 billion (0.2% of the Brazilian GDP); an evidence that certification adds economic value to a product. The overall combined impact on steel totals USD 4.5 billions. The other products yield similar trends as clearly shown in Table 6, summarizing the overall economic impact at glance.

Further studies are underway to investigate the economic impact of primary products and semi-manufactured goods (e.g. sugar and alcohol) on trade given their economic weight.

The introduction of internationally accepted certification procedures (of the voluntary and compulsory nature) has given rise to a positive economic impact in the production of different goods, therefore enhancing trade. Based on this rationale, it seems fair to conclude that this type of conformity assessment procedure in fact does reduces asymmetry of information, which would compromise trade efficiency. In most areas of industrial technology, standards and certification are efficient tools to reduce those undesirable asymmetries. From the trade perspective, globalization could be seen as a benign force for delivering economic prosperity. Hence, successful commercial transactions require product certification, which is a metrological guarantee that the product complies with internationally accepted technical and administrative specifications and standards. In this context, standards and product certification provide key information to remedy distortions created by information asymmetries between trade partners.

Acknowledgement

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Appendix I
Basic elements of a sound MSTQ system

The basic MSTQ system shall comprise:

1. A National Metrology Laboratory: To provide basic metrology services at the highest accuracy level and responsible for the establishment, maintenance and dissemination of measurement units through national measurement standards. Of crucial importance for establishing confidence in any measurement results, metrology furnishes the use of appropriate measurement techniques and corrects calibration through the determination of metrological characteristics of an instrument by direct comparison to a well established and internationally recognized standard. Through an unbroken chain of comparisons (“traceability”), results of measurements performed at the marketplace are related to higher levels of measurement standards and, ultimately, any measurement of a specific physical quantity to the international standard.

2. A National accreditation scheme: A formal system ensuring confidence in the capabilities and competence of conformity assessment bodies (laboratories and certifying bodies) by attesting that (i) calibration and testing laboratories are capable of delivering reliable measurements and services needed to ensure quality of goods, and (ii) that certifying bodies are capable of formally demonstrating compliance of products with technical specifications required by regulators of trading partner countries. Accreditation bodies are authoritative bodies giving formal recognition of the competence of an organization to carry out specific tasks. Accreditation is particularly important when users – regulating authorities or purchasers/suppliers – are not in a position to evaluate themselves the competence of a conformity assessment provider. This may be due to the technical complexities faced by sellers and buyers during a transaction. In the case of international trade, whenever there exists spatial separation between a conformity assessment body in the exporting country and the importer, accreditation must, always, be independent of both.

3. Calibration laboratories: As for calibration laboratories, their programme for calibration of equipment shall be designed and operated to ensure that calibrations and measurements made by the laboratory are traceable to the International System of Units, SI (Système International d’Unités). Calibration laboratories must ensure “traceability” of measurement results to a reference standard with stated uncertainties in the level of precision. Calibration laboratories must be accredited according to international standards and best practices ensuring that measuring equipment used in the marketplace produce internationally recognized reliable results, therefore traceable to the SI measuring system. A calibration laboratory accredited under the international standard ISO/IEC 17025 is a laboratory internationally recognized to be competent, capable to issue calibration certificates bearing the accreditation body logo for the calibration concerned, and capable to provide sufficient evidence of traceability of the calibration data reported, therefore linked to SI units.

4. Testing laboratories and inspection: Testing of individual specimens or samples is the main technique to determine the characteristics of a product. Testing is usually undertaken by specialized laboratories – testing laboratories – often making use of sophisticated instruments which are responsible for evaluating compliance of products and services to standards. A related form of assessment often combined with testing but not always clearly distinguished as such is the inspection of products. With the expansion in commercial relationships developed worldwide and the increased complexity of products, inspection activities relied on subjective judgment and technical expertise of inspectors are complemented by objective and standardized procedures conducted by internationally recognized competent testing laboratories. Both inspection and testing may be performed by the manufacturer, the customer, regulatory authorities or by commercial service organizations hired on behalf of any interested party, held liable for their technical reports on the products examined.

5. Certifying bodies: From the conformity assessment point of view (ISO/IEC 17000:2004), certification is a third-party attestation related to products, processes, systems or persons. Certification is a formal attestation (“certificate”) that the product meets the required standard or customer specifications (beyond the inspection or laboratory test reports). Certification allows for the right to use a certification mark on the product or packaging licensed to the producer. Certification goes beyond testing and inspection in several respects since product (or processes) characteristics are assessed against a specific standard, whether mandatory or voluntary, which is not necessarily the case for testing and inspection. Certification gives additional
confidence on account of the systematic intervention of a competent third-party that is always independent of either the purchaser or the manufacturer. Certification is particularly required when the seller or buyer wishes to communicate compliance with a standard to a larger public or governmental authority, usually in response to trade needs and/or health and safety concerns. Certification bodies normally have expertise in specific product areas and use inspection, testing, evaluation of manufacture’s quality management systems and combinations of those activities in order to both assess samples of the product and/or monitor production. They may rely on their own technical resources and also refer, whenever needed, on external inspection and testing facilities. Certification bodies may also periodically retest samples of product purchased in the market. May provide for ongoing surveillance and, in the case of deficiencies are uncovered, may revoke their certificate/mark. Certifying bodies, understood as conformity assessment bodies, in turn, certify products and services to meet the trade goal “tested once accepted everywhere” thereby eliminating unnecessary delays and costly duplication incurred by re-testing. Product certification is a guarantee that a given product traded met stipulation of Conformity (ISO/IEC 17021: to replace ISO/IEC Guide 27:1998) and Accreditation (ISO/IEC 17011:2004).


Note 2: ISO/IEC 17050-1:2004 (Conformity Assessment: Supplier’s declaration of conformity) has been developed with the objective of providing general requirements for a supplier’s declaration of conformity. It addresses one of the three types of attestation of conformity, i.e., attestation undertaken by the first party (e.g. supplier of a product). Other types of declaration not covered by the standard are attestations by second-party (e.g. where a user issues an attestation for the product) and by a third-party (e.g. issued by an accredited organization which maintains total independence of suppliers and buyers of the product, with no interest in the product commercialization). Each of these three types is used in the market in order to increase confidence in conformity of a product.

Appendix II

E-views statistical variables

Regression coefficient, the \( \beta \)'s are obtained from the matrix equation \( \beta = (X'X)^{-1}X'Y \).

Standard errors (the statistical reliability of the estimated coefficients) computed from: \( \bar{u} = Y - X\beta \).

\( t \)-Statistics, computed as the ratio of the estimated coefficient to its standard error.

Probability, the marginal significance level, i.e., a \( p \)-value measure to indicate whether the relationship of causality between dependent and independent variables can be rejected or not. For example, if a test is being performed at the 1% significance level, a \( p \)-value greater than 0.001 is taken as a criterion to reject the hypothesis of causality.

\( R \)-squared \(( R^2 \), a measure of the success of the regression in predicting the values of the dependent variable in the sample. \( R^2 \) is the fraction of the variance of the dependent variable expressed in terms of the independent variables.

\[
R^2 = 1 - \frac{\hat{u}'u}{(Y - \bar{Y})'(Y - \bar{Y})}
\]

where \( \bar{Y} = \sum_{i=1}^{T}Y_i/T \).

Adjusted \( R \)-squared, commonly denoted as \( \bar{R}^2 \), a measure in multiple regression analysis that penalizes additional explanatory variables when a degree of freedom to estimating the error variance is used. The adjusted \( \bar{R}^2 \) is computed as

\[
\bar{R}^2 = 1 - (1 - R^2) \frac{T - 1}{T - k}
\]
Standard Error of regression, a measure based on the estimated variance of the residuals. The standard error of the regression is computed as

\[ s = \sqrt{\hat{u}'\hat{u} / (T - k)}, \quad \hat{u} = Y - X\beta \]

Sum of squared residuals, used in a variety of statistical calculations, given by the equation:

\[ \hat{u}'\hat{u} = \sum_{i=1}^{T} (Y_i - X_i\beta)^2 \]

Durbin–Watson statistics, a statistical test designed to detect errors that follow a first-order autoregressive process and is computed by the expression:

\[ DW = \frac{\sum_{i=2}^{T} (\hat{u}_i - \hat{u}_{i-1})^2}{\sum_{i=1}^{T} \hat{u}_i^2} \]

Mean and standard deviation (SD), computed by the standard formulae.

\[ \bar{Y} = \frac{\sum_{i=1}^{T} Y_i}{T}, \quad s_Y^2 = \frac{\sum_{i=1}^{T} (Y_i - \bar{Y})^2}{(T - 1)} \]

Akaike information criterion, computed by

\[ AIC = -2l/T - 2k/T \]

The Schwarz criterion (SC), a criterion designed to help in the selection of the better of two alternate models:

\[ SC = -2l/T + (k \log T)/T \]

F-Statistics and probability, which provides an indication of the lack of fit of the data to the estimated values of the regression. For ordinary least squares models, the F-statistics is computed by

\[ F = \frac{R_1^2 / (k - 1)}{(1 - R_1^2) / (T - k)} \]

Appendix III

The validation procedure of the econometric method

This appendix describes the classical procedure to validate the econometric method based on the following statistical parameters:

Linearity: Verified by the EViews software (scatter-plot).

Independence: The principle of independence is based on the random character of the residuals with respect to time, usually caused by lack of linearity between variables. This assumption was guaranteed by the EVIEWS built-in Durbin–Watson-test. It measures the serial correlation present in the residuals of first order (u); i.e., in the \( (Y_t - Y_{t-1}) \) correlation calculated from the vector of the remainders \( (u = y - X\beta) \), defined by the following relation:

\[ d = \frac{\sum_{i=1}^{n} (u_i - u_{i-1})}{\sum_{i=1}^{n} u_i^2} \]

The assumption “independence” is satisfied when the parameter “d” lies in the interval [0,4]; If \( d \geq 2 \) then a small residual autocorrelation can be obtained; if \( d < 2 \) a positive correlation and if \( d > 2 \) a negative correlation.

Homoscedasticity (constant variance): This assumption supposes that the variance of the residuals is constant in time. Violation of this assumption generates unstable results which artificially scale variables of smaller importance. To identify homocedasticity, several tests are available in the literature [15,16]; the test of White [17] was preferred as it does not require specification of variables, using an auxiliary least squared regression of the residuals. This is as follows:

\[ u_t^2 = \alpha_1 + \alpha_1X_1 + \alpha_2X_2 + \alpha_3X_1^2 + \alpha_4X_2^2 + \alpha_5X_1X_2 + v_t \]

Based on this new regression it is possible to evaluate the \( \alpha \) coefficients (associated with a probability p-value) which appear in the above equation. This probability p-value is used as a criterion to discard the existence of a possible homoscedasticity structure.

Normality: This is the least crucial of the regression assumptions and is used to check whether or not the error term follows a normal distribution. This assumption can be verified by the test of Jarque–Bera (JB) [18], given by the following expression:

\[ JB = \frac{N - k}{6} (s^2 - \frac{1}{4} (K - 3)^2) \]

where \( S \) is the skewness, \( N \) the total number of events, \( K \) is the kurtosis (number of estimated coefficients used to create the series).

References
