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BNDES' impact on steel industry efficiency: a two-stage Malmquist model usage

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Abstract

Using two-stage Malmquist-DEA analysis, this article aims to evaluate how the Brazilian National Development Bank – BNDES impacts the performance of the steel industry. The study conducts a Malmquist Index decomposition and nonlinear robust regression, testing the impact of contextual variables. The research hypothesis of positive impact over steel industry performance cannot be supported by the model's results, which suggests a negative coefficient on the catching up effect. Few examples of quantitative research on national development can be highlighted, mainly focused on theoretical and qualitative issues. The study contributes to the field by making use of a settled methodology to highlight and measure firms efficiency performance. Nevertheless, due to limitations derived from the sample selected and the applied methodology, further research must be carried out, mainly to deal with social outcomes derived from this kind of public policy.

Keywords: BNDES. Malmquist Index. Efficiency. Steel industry.

Impacto do BNDES na eficiência da indústria siderúrgica: aplicação do modelo Malmquist de dois estágios

Resumo

Utilizando o modelo Malmquist de análise envoltória de dados (Data Envelopment Analysis – DEA) de dois estágios, este artigo busca avaliar como o Banco Nacional de Desenvolvimento Econômico e Social (BNDES) impacta o desempenho da indústria siderúrgica. Para tanto, são conduzidas a decomposição do índice de Malmquist e a regressão não linear robusta para testar o impacto das variáveis contextuais consideradas. A hipótese da pesquisa de impacto positivo sobre a indústria siderúrgica não é suportada pelos resultados do modelo, indicando um coeficiente negativo sobre o efeito *catching up*. Pode-se destacar poucos exemplos de pesquisa quantitativa sobre o tema, a maioria com foco teórico ou qualitativo. Este artigo contribui com o campo de pesquisa ao adotar uma metodologia estabelecida para a identificação e a mensuração do desempenho de eficiência das firmas. Entretanto, em razão de limitações da amostra selecionada e da metodologia aplicada, há necessidade de novas pesquisas, principalmente para avaliar os resultados sociais desse tipo de política pública.

Palavras-chave: BNDES. Índice de Malmquist. Eficiência. Indústria siderúrgica.

Impacto del BNDES sobre la eficiencia de la industria siderúrgica: aplicación del modelo Malmquist de dos etapas

Resumen

Utilizando el modelo Malmquist-DEA de dos etapas, el presente artículo busca evaluar cómo el BNDES impacta el desempeño de la industria siderúrgica. Para ello, se realiza la descomposición del índice de Malmquist y regresión no lineal robusta para testar el impacto de las variables contextuales. La hipótesis de la investigación de impacto positivo sobre la industria siderúrgica no es soportada por los resultados del modelo, lo que indica un coeficiente negativo sobre lo efecto *catching up*. Se pueden destacar pocos ejemplos de investigación cuantitativa sobre el tema, la mayoría con foco teórico o cualitativo. Este artículo contribuye a este campo de estudio al adoptar una metodología establecida para la identificación y medición del desempeño de eficiencia de las firmas. Sin embargo, en razón de las limitaciones de la muestra seleccionada y de la metodología aplicada, son necesarias nuevas investigaciones, principalmente para evaluar los resultados sociales derivados de ese tipo de política pública.

Palabras clave: BNDES. Índice de Malmquist. Eficiencia. Industria siderúrgica.

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INTRODUCTION

This article examines the possible impacts on the efficiency of the firms resulting from financing offered by public banks of economic development (development banks). This issue is part of a wider scope of public-private relations in which the State operates through institutional regulations or in a more active way either by public spending or by providing public financing. In developing economies, in particular by means of development banks, this type of activity by the State in promoting industrialization and productive infrastructure has the objective of productive modernization and economic development (LAZZARINI, MUSACCHIO, BANDEIRA-DE-MELO et al., 2015; AGHION, 1999). Until recently, a significant part of the long-term credit was provided by these banks, especially the Brazilian National Development Bank (BNDES) being one of the largest banks in terms of number and volume of transactions (TORRES and ZEIDAN, 2016).

However, the most recent quantitative studies have concentrated on assessing the effects of public spending on private investment (SONAGLIO, BRAGA, and CAMPOS, 2010; MELO and RODRIGUES JÚNIOR, 1998; TADEU and SILVA, 2013; SHANMUGAN, 2017). Alternatively, as for development banks, there is a gap of quantitative studies with the largest part of the research being in public banks in general (LA PORTA, LÓPEZ-DE-SILANES and SHLEIFER, 2002; CARVALHO, 2014; YEYATI, MICCO and PANIZZA, 2007; ANDRIANOVA, DEMETRIADES and SHORTLAND, 2008), or following theoretical and qualitative scopes (BOND, 2013; BRUCK, 1998; GUTIERREZ, RUDOLPH, HOMA et al., 2011; HOCHSTETLER and MONTERO, 2013; TORRES and ZEIDAN, 2016).

One of the few quantitative studies on development banks focuses the impact on the level of investments (LAZZARINI, MUSACCHIO, BANDEIRA-DE-MELO et al., 2015). However, there is still a gap in the research in relation to the impact from the role of the development banks on the efficiency of the firms receiving financing.

Extensive research has been carried out over the past few years on sector efficiency based on parametric and non-parametric approaches. The main sectors to be studied have been banking (FUKUYAMA and MATOUSEK, 2017; AZAD, MUSIMAMY, MASUM et al., 2016; BAHRINI, 2015; BARROS and WANKE, 2014; LEE and KIM, 2013; REZVANIAN, RAO and MEHDIAN, 2008), insurance (WANKE and BARROS, 2016; BARROS, DUMBO and WANKE, 2014), infrastructure (MARCHETTI and WANKE, 2017; ESTACHE, DE LA FÉ, and TRUJILLO, 2004; SARKIS, 2000), and industry (LI and LIN, 2015; HE, ZHANG, LEI et al., 2013; MA, EVANS, FULLER et al., 2002).

The objective of this article is to complement the line of research on public banks by addressing the impact on the efficiency of the firms based on non-parametric modeling of Data Envelopment Analysis (DEA). In particular, the Malmquist model of DEA and later non-linear regression to test the effects of contextual variables on the Malmquist efficiency indexes for companies in the steel sector. The study of this sector of economic activity can be justified due to its relevance in both economic growth and for increasing industrialization due to the spillover effects (HUH, 2011). Furthermore, the steel industry in Brazil is one of the main recipients of funding from BNDES in the period considered. In addition to this introduction, the article is organized as follows: section 2 presents the role of BNDES and of the steel industry, section 3 presents the literature review covering studies on public development banks as well as the recent literature applying efficiency modeling with an emphasis on the Malmquist models, section 4 presents the data and methodology applied, and section 5 analyzes and discusses the results highlighting the significance of the contextual variables. Finally, the conclusions suggest implications of public policies, the study's limitations, and possibilities for future research.

CONTEXT

Brazilian National Development Bank (BNDES)

BNDES is one of the largest development banks in the world and has taken on a significant role in offering long-term credit in Brazil in recent years (TORRES and ZEIDAN, 2016). According to Colby (2012), the bank's three main activities can be listed as: a) complement the offer of credit, b) economic restructuring, and c) countercyclical policies. While the first and the third would have a horizontal nature, the second would take on a vertical nature aiming at the productive structure by means of reorientation or creation of new competitive advantages.

The magnitude of its participation in the Brazilian economy has increased since the global financial crisis of 2008 in three aspects: (a) financing of productive investment, (b) granting of guarantees, and (c) sectoral consolidations through mergers and acquisitions of companies. The bank has also taken on a key role in making major infrastructure projects feasible in the sectors of oil & gas, energy, and logistics. Consequently, this set of capital intensive projects began to have a growing weight in the bank's portfolio of assets. This growth in the bank's role corresponded to a growth in financial resources by the National Treasury and from specific funds such as the Worker's Welfare Fund (FAT, acronym in Portuguese)

The bank is currently in a paradigm shift due to the coming together of three factors: (a) retraction of the Brazilian economy, (b) the impeachment process, and (c) upward trend of public deficit. This situation reflects in a reduction of productive activity and consequently the demand for financing for productive investment along with a new round of divestiture of assets and concession of public services in infrastructure that require different instruments of institutional action on the part of BNDES.

Parallel to this, a debate begins about the size of the Brazilian State and consequently about the standard of BNDES's recent actions. Some of the main issues that arise in this debate refer to the selection of projects—strategy of the "national champions", return of resources to the National Treasury, and readjusting the long-term interest rate (LTIR).

The Steel Sector

Throughout the 20th century, the standard of industrial mass production was built around capital-intensive industries and of scale focused on the production of consumer durables and capital goods. The steel industry arose among the intermediate industries supplying inputs because of its relation with the construction industry through the production of long products (cables, rebars) and with the metal-mechanical complex through flat products (plates, coils). Economic development was interpreted as the increasing incorporation of these industries into the productive matrix, hence the relevance of the steel sector for building more complex and dynamic productive matrices (HUH, 2011).

Waves of forced development and industrialization were observed by different groups of developing countries with the application of industrial policies focused on setting up steel complexes integrated with their respective economies. In chronological order we can list Japan, subsequently South Korea, and in recent decades mainly China and India (LEE and KI, 2017; HUH, 2011; DEBNATH and SEBASTIAN, 2014; WU, 2000). Specifically regarding the South Korean and Chinese companies, there are specific sites that have been interpreted as relevant for their productive and economic performance. While the former presents economic integration with the metal-mechanical chain geared to exports, especially the automobile industry, household appliances, and shipbuilding (HUH, 2011), the latter is linked to the growth of domestic demand, bringing together both the metal-mechanics industry and civil construction while increasing the offer of infrastructure services (WU, 2000; SUN, DONG, and ZHAO, 2017).

In Brazil, the incorporation of the steel industry was directly linked to its industrial policy of putting in place a set of state companies. Beginning in the 1990s, simultaneous processes took place of economic opening, deregulation of markets, and privatization resulting in the formation of three large private economic groups: Companhia Siderúrgica Nacional (CSN), Usiminas, and Gerdau (MONTERO, 1998). Later on the multinational company Arcelor Mittal entered the market through acquisition and consolidation of the former state productive capacity (Companhia Siderúrgica de Tubarão – CST) and private companies (Mendes Junior). The Brazilian steel sector also presents characteristics that are relevant to its performance such as productive integration with the main raw material, iron ore, as well as with the logistics infrastructure for the distribution of steel products to the domestic market and of iron ore abroad.

LITERATURE REVIEW

Development Banks

The debate about the interaction of the State with the market implies in arguments that oppose complementarity — correction of market failures and competition for economic resources (HICKS, 1937). Quantitative researches on the effect of public spending on the private sector conducted mainly in developing economies reach different results depending on the sample of countries and temporal space considered. There is a set of studies indicative of crowding-out of public spending on private spending (SONAGLIO, BRAGA and CAMPOS, 2010; MELO and RODRIGUES JÚNIOR, 1998) and another indicating crowding-in specifically in relation to the infrastructure sector (TADEU and SILVA, 2013; SHANMUGAN, 2017).

As for development banks, an evolution can be observed both in their way of operating as well as in the line of research. After an initial period of an active public policy geared to industrialization characterized by long-term financing, the next phase was one of financing the privatization of infrastructure along with a countercyclical role in response to the international financial crisis, adopting new forms of intervention such as minority shareholding and providing guarantees (TORRES and ZEIDAN, 2016; HOCHSTETLER and MONTERO, 2013). Recent research, however, on the role of development banks considers a series of risks and costs as an effect that distorts investment decisions, as well as crowding-out on the private banking sector, resulting in a negative impact on economic growth, hoping to stimulate a rent-seeking behavior on the part of the market (LAZZARINI, MUSACCHIO, BANDEIRA-DE-MELO et al., 2015). As for the quantitative research (LAZZARINI, MUSACCHIO, BANDEIRA-DE-MELO et al., 2015) on the other hand, neither was significance found of BNDES on the private investment, nor a rent-seeking behavior by the economic agents in relation to electoral financing.

In spite of the risks and costs related to the development banks, their presence in many countries indicates a function of providing long-term credit that would be relevant for projects of social value to the extent that they would mitigate the effect of market failures and externalities (YEYATI, MICCO and PANIZZA, 2007) and address problems related to the insufficiency of effective demand due to radical uncertainty (FERRAZ, ALÉM and MADERA, 2013). According to the post-keynesian approach, the presence of radical uncertainty would be relevant for forming the investment decisions of the private agent, which corresponds to a negative impact on the level of effective demand. In this sense, by providing long-term funding, the development banks could play a fundamental role for enabling and sustaining the level of investments, especially in activities more subject to the negative impact of uncertainty, corresponding to high capital expenditures, long periods of maturation of the investment, and significant social impacts such as externalities resulting from innovations. Of the roles assigned to these banks of correcting market failures, sustaining the level of investments, and promoting development, this last one is viewed as being the most efficient use of economic resources. The hypothesis to be tested in this article can therefore be extracted as follows:

- **H1:** BNDES credit promotes the efficiency of the recipient firm.

The Steel Sector

Recent research on the steel sector indicates intensive use of energy and capital (DEBNATH and SEBASTIAN, 2014; NIELSEN, 2017) as well as a correlation with the dynamics of growth of the gross domestic product (GDP) and industrial competitiveness by creating integrated productive chains (HUH, 2011). This dynamic would have a positive impact on the steel sector by stimulating the investment and feasibility of larger production scales. In this sense, scale economies would have an important role in the performance and efficiency of the steel sector (DEBNATH and SEBASTIAN, 2014; NIELSEN, 2017; HUH, 2011; WU, 2000; KIM, LEE, KIM et al., 2006). This growth dynamic, however, would induce an asymmetric mechanism to increase capacity, resulting in inefficient allocation of resources in the long term (SUN, DONG, and ZHAO, 2017).

Furthermore, the investment would have a positive impact on efficiency, to the extent that it represents production modernization, by incorporating newer equipment and plants (KIM, LEE, KIM et al., 2006). This modernization effect specifically would be inserted into contexts of windows of opportunity, which would explain the catching up, for example, of the Japanese and South Korean companies (LEE and KI, 2017).

Efficiency Analysis

Since the establishment of the DEA methodology (CHARNES, COOPER and RHODES, 1978), there has been a significant growth in research concerning the efficiency of firms in various sectors of economic activity. A significant part of the articles focus on the sectors of infrastructure and financial services, which are subject to regulation by the State and therefore potentially indicative of direction for public policies. Furthermore, as for the industrial sectors, there is a tendency for research to be done with a focus on environmental issues or energy efficiency (LI and LIN, 2015; HE, ZHANG, LEI et al., 2013). Specifically regarding the steel sector, the research has focused on financial indicators, energy consumption, and emission of pollutants (DEBNATH and SEBASTIAN, 2014; NIELSEN, 2017; KIM, LEE, KIM et al., 2006). Box 1 presents the literature review on efficiency analysis.

Traditionally the research has concentrated on the estimation of the efficiency frontiers and in identifying the positioning of the firms in relation to the frontier (BARROS, DUMBO, and WANKE, 2014; LI and LIN, 2015; HE, ZHANG, LEI et al., 2013; ESTACHE, DE LA FÉ, TRUJILLO, 2004; MA, EVANS, FULLER et al., 2002; SARKIS, 2000). In general, the Malmquist Productivity Index (MPI) is used for evaluating the interfirm performance, highlighting the dynamic effects of displacing the efficiency frontier.

More recently, especially in the banking sector, the DEA methodology of estimating efficiency has been used in two stages associated with econometric methods such as generalized linear models, panel data, and bootstrap truncated regression. Thus, relations can be identified between the efficiency indexes and explanatory contextual variables (MARCHETTI and WANKE, 2017; AZAD, MUSIMAMY, MASUM et al., 2016; BAHRINI, 2015; LEE and KIM, 2013). This greater complexity of the research allows implications for formulating public policies and for decision-making processes.

In particular, Bahrini (2015) and Lee and Kim (2013), respectively, applied two-stage MPI models in order to identify the explanatory contextual variables on the performance of Islamic and Koreans banks. While the performance of the Islamic system is related to the banking variables (capitalization, size, profitability, credit risk), the performance of the Korean banking sector would be more related to the type of the bank's ownership — international or public.

Due to the growing application of two-stage models for estimating efficiency, especially in the banking sector that include accounting variables, the choice of the methodology of this research uses this type of procedure in order to fill the gap of quantitative studies regarding the impact of the financing from development banks in the performance of the firms.

Box 1

Literature Review - analysis of efficiency

Author/ Year	Research Proposal	DMU	Method	Country	Inputs	Products	Context Variables
Sarkis (2000)	Evaluation of the operational efficiency of 44 airports	220	DEA	USA	OPEX, employment, gates, departures	Operating revenues, movement of aircraft, general aviation, passengers, freight	-
Ma, Evans, Fuller et al. (2002)	Operational efficiency of the steel sector	711	MPI	China	Employment, fixed capital, energy, age, working capital	Production	-
Estache, De La Fé and Trujillo (2004)	Breaking down of the sources of efficiency gains in the port sector	44	MPI	Mexico	Dock area, employment	Volume of merchandise traded	-

Continue

Author/ Year	Research Proposal	DMU	Method	Country	Inputs	Products	Context Variables
Kim, Lee, Kim et al. (2006)	Sources of productive efficiency	22	SFA	Several countries	Employment, productive capacity, raw material	Production of crude steel	Ownership (private or public), plant age, scale
Rezvanian, Rao and Mehdian (2008)	Evaluation of the effect of the ownership on the efficiency of the banking sector	540	MPI	India	Funds borrowed, employment, fixed assets	Loans, securities, other revenues	-
Feng He et al. (2013)	Energy efficiency and productivity variation in the steel sector	400	MPI and MPLI	China	Net fixed assets, employment, energy	Added value, gaseous waste, liquid waste, solid waste	-
Lee and Kim (2013)	Determinants of bank performance. Comparison between ROE and ROA.	136	MPI Panel data analysis- fixed effects	South Korea Extended to China and Japan	Interest expenses, costs of fees, operating expenses, provision for losses	Interest income, revenue from fees	Assets, assets^2, risk, GDP growth, and dummy (public, foreign, merger)
Barros and Wanke (2014)	Analysis of banking efficiency	-	Dynamic Bayesian Frontier	Brazil	-	-	Price of labor, cost of capital, price of deposits, total loans, total securities, dummy variables (public, foreign, merger, large, deregulation, stressed banks)
Barros, Dumbo and Wanke (2014)	Efficiency analysis of insurance companies	70	Main component analysis, Bootstrapping DEA, and neural networks	Angola	OPEX, employment, salaries, capital	Insurance paid, profits paid, premiums paid, reinsurance ceded	-
Debnath and Sebastian (2014)	Efficiency in the steel sector	22	BCC Model	India	Employment, fixed assets, current assets, and energy	Income, profits before and after taxes, sales	-
Bahrini (2015)	Analysis of the Total Factor Productivity (TFP) in the Islamic banking sector	198	Bootstrapped MPI	MENA (Middle East & North Africa)	Employment, fixed assets, deposits	Total loans, portfolio investment, non-operating revenues	Banking, macroeconomics, temporal dummies, and dummy for the global financial crisis
Li and Lin (2015)	Method for measuring growth of green productivity	504	MLPI	China	Capital stock, use, energy	Gross industrial product, CO2 emissions	-

Continue

Author/ Year	Research Proposal	DMU	Method	Country	Inputs	Products	Context Variables
Azad, Musimamy, Masum et al. (2016)	Banking efficiency	215	Two-stage DEA. Simar model of dual regression bootstrap	Malaysia	Expenses with interest rates, salaries, OPEX, capital, deposits	Earnings from interest, net income, deposits, loans	Banking, macroeconomics, ownership, and the bank's nature
Da Silva, Martins-Filho and Ribeiro (2016)	Banking efficiency	1840	DEA, DEAC, FDH, FDHC, conditional quartile models of order m and α	Brazil	Employment, fixed capital, other capital assets, resources from third parties	Net credit lines, financial investments, other credit lines	Dummies (property - public, private, foreign; size- large, medium, small, micro)
Marchetti and Wanke (2017)	Efficiency of the railway sector	60	DEA. Bootstrap truncated regression.	Brazil	Cars, employment	Volume transported (TKU)	Dummies (mineral commodities, agricultural commodities, connection, type of regulation)
Nielsen (2017)	Efficiency of the steel sector	21	DEA CRS and VRS	Market and planned economies	Energy and raw materials (coal, iron, and scrap)	Production of crude steel and pig iron	

Source: Elaborated by the authors.
DEA = data envelopment analysis; DEAC = bias corrected DEA; FDH = free disposal hull; FDHC = bias corrected FDH; MPI = Malmquist productivity index; MPLI = Malmquist-Luenberger productivity index.

METHODOLOGY

This research applies a two-stage model to estimate the role of efficiency. The growth ratio method of Malmquist productivity oriented to the product will be used to obtain the productivity indexes (Malmquist Index), as well as the portions corresponding to the frontier approximation effect (Technical Change) and frontier displacement (Frontier Shift). Next a non-linear robust regression approach is applied to test the impact of the contextual variables on the Malmquist index. All estimates were performed in R using the following packages: *nonparaeff* (Malmquist index); mgcv, gamlss, MCMCpack, MCMCglmm, and DEoptim (robust regression).

Malmquist Index

The Malmquist Productivity Index can be broken down into two components related to interfirm efficiency gain (catching up effect) and displacement of the efficiency curve (technological change) between period t and t+1 (FARE, GROSSKOPF, NORRIS et al., 1994) according to equation (1):

(1) PRODch = EFFch X TECHch with,

(2) PRODch = $\left(\frac{D_0^t(x^{t+1},y^{t+1})}{D_0^t(x^t,y^t)} \frac{D_0^{t+1}(x^{t+1},y^{t+1})}{D_0^{t+1}(x^t,y^t)}\right)^{1/2}$

(3) EFFch = $D_0^{t+1}(x^{t+1},y^{t+1})/D_0^t(x^t,y^t)$

(4) TECHch = $\left(\frac{D_0^t(x^{t+1},y^{t+1})}{D_0^{t+1}(x^{t+1},y^{t+1})} \frac{D_0^t(x^t,y^t)}{D_0^{t+1}(x^t,y^t)}\right)^{1/2}$

Where,

D0 - maximizing function of relative distance (FARE, GROSSKOPF, NORRIS et al., 1994).

These indexes are allocated to the following function to which the robust regression is applied:

(5) $Y_{jz} = \beta_0 + \beta_i \sum X_i + \beta_2 BNDES + Brasil + China + Coreia + \beta_i \sum Z_i + \varepsilon_j$

Being,

j – DMU

z – PRODch, EFFch, TECHch

Xi - accounting-financial contextual variables specific for the firms (price of labor, cost of capital, EBITDA/asset ratio, CAPEX/assets ratio, leverage)

Zi - socioeconomic contextual variables (GDP growth, GDP by purchasing power parity - GDP PPP, inflation, Human Development Index (HDI), Gini Index, Foreign Direct Investment - FDI, energy use, life expectancy, infant mortality, global innovation, and logistics performance)

BNDES - dummy variable (financing granted by the bank in year t)

Brazil - dummy variable for Brazilian company

China - dummy variable for Chinese company

Korea - dummy variable for South Korean company

While the dummy BNDES represents the hypothesis to be tested by the model, the dummies for Brazil, China, and Korea were applied due to the specifications mentioned in the section Context. In turn, the socioeconomic contextual variables would be related to greater economic development and competitiveness as mentioned in the section Context regarding the relevance of the level of business activities.

Non-linear stochastic robust regression approach

In this approach, the following regression methods were combined for applying the bootstrapping and non-linear stochastic programming technique: OLS (ordinary least squares), GLM (generalized linear model), GAM (generalized additive model), GAMLSS (generalized additive model for location, scale, and shape), MCMC-GLMM (Markov chain Monte Carlo and generalized linear mixed model) and MCMC-Gaussian Linear (Markov chain Monte Carlo and Gaussian linear model). All these methods are properly described in Faraway (2006). This combination is justified because most of the regression approaches generate biased results in the two-stage DEA. This can be mitigated by using the bootstrapping technique (SIMAR and WILSON, 2007, 2011) and by the combination of forecasts to return to a smaller variance of errors (JAMES, WITTEN, HASTIE et al., 2013; LEDOLTER, 2013).

The problem of non-linear stochastic optimization for combining the regressions after applying the bootstrapping is presented in model (6) where w1, w2, w3, w4, w5, and w6 represent weights between 0 and 1 are assigned to the vectors of the regression residuals. This model optimizes the values of w so that the variance (Var) of the combined residuals (Ri) is minimal. Bootstrapping was applied to all regressions and were recombined 100 times, allowing a distribution of the profile w to be collected for the best estimates of efficiency scores and of the weight division model. The residual variances were collected assuming the linear model for each of these regressions, linking the efficiency/division of weights estimates with the contextual variables.

$$\begin{aligned}
&\min Var(w_1\boldsymbol{R1} + w_2\boldsymbol{R2} + w_3\boldsymbol{R3} + w_4\boldsymbol{R4} + w_5\boldsymbol{R5} + w_5\boldsymbol{R6}) \\
&S.T. \\
&\sum_{i=1}^{6} w_i = 1 \\
&0 \leq w_1 \leq 1 \\
&0 \leq w_2 \leq 1 \\
&0 \leq w_3 \leq 1 \\
&0 \leq w_4 \leq 1 \\
&0 \leq w_5 \leq 1 \\
&0 \leq w_6 \leq 1
\end{aligned} \qquad (8)$$

Model (8) was solved by means of the differential evolution (DE) technique (THANGARAJ, PANT, BOUVRY et al., 2010; MULLEN, ARDIA, GIL et al., 2011). Additional references can be found at Ardia, Boudt, Carl et al. (2011).

DATA ANALYSIS AND DISCUSSION OF THE RESULTS

Data

In recent years, projects in the steel sector have been some of the main recipients of funding from BNDES[1]. Because of this, the companies in this sector were selected as the object of analysis in this study. Considering the small number of Brazilian firms, we opted for a sample that included some of the largest international competitors. The sample selected of 34 companies was obtained based on a pre-selected sample made by Bloomberg[2,3]. Furthermore, due to the availability of data for the variables considered, the analysis was restricted to the period 2010-2015.

The raw data set was worked on to make it possible to be used with the MPI model, specifically regarding the restriction to non-zero values for inputs and products. The application of the model to the natural logarithms of the variables also required treatment for negative and zero values. The procedure adopted was the transformation of the data to a 0-1 scale, adding 2 to each observation for posterior logarithmic transformation.

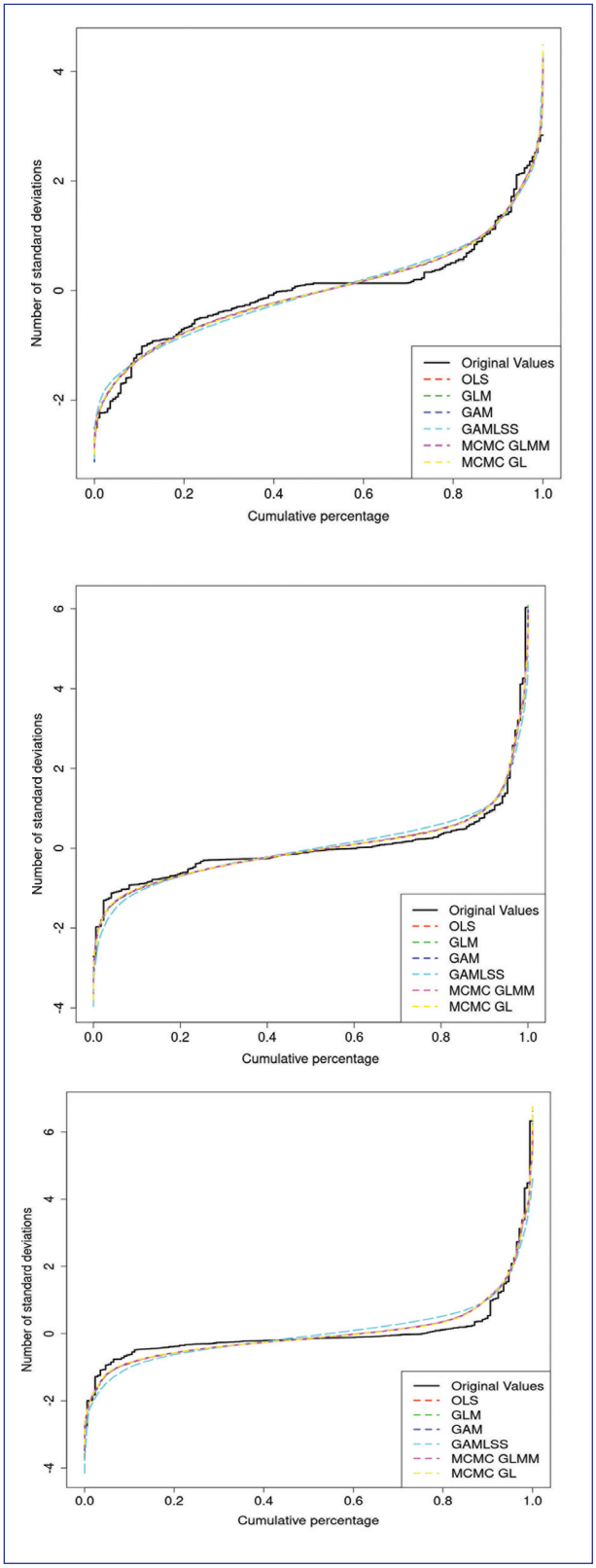
Results

As for fitting the distributions into the MPIs, Figure 1 describes the adjustments of the OLS, GLM, GAM, GAMLSS, MCMC-GLMM, and MCMC-Gaussian Linear regressions for their non-conditional inverse accumulated distributions. However, it is not possible to affirm in principle if a specific distribution is preferred in detriment to another. This suggests that a combination of results from these regressions would be a more appropriate approach. In fact, the results for the Kullback-Leibler (KL) divergence test presented in Table 1 for conditional distributions of MPIs indicates that the differences between both the adjustments is minimal for most distributions assumed, sometimes favoring a distribution, which means a specific type of regression, in detriment to another.

[1] The file of contracts is available at <www.bndes.gov.br>.
[2] Anyang, Arcelor, Azovstal, Baosteel, Beijing, China, CSN, Eregli, Gerdau, Guangri, Hesteel, Hunan, Hyundai, JFE, Kobe, Liuzhou, Maanshan, Magnito, Mechel, Nippon, Novolipetsk, Nucor, Pangang, Posco, SAAB, Severstal, Shandong, Steel Dynamics, Ternium, TSK, US Steel, Usiminas, Voestalpine, and Xinyu.
[3] Data collected from Bloomberg and complemented with information provided in the Annual Reports and Financial Forms available on the websites of the firms.

Figure 1

KL divergence for Technical Change (high), Frontier Shift (mean), and Malmquist Index (low)



Source: Elaborated by the authors.

Table 1

Results of the KL Divergence

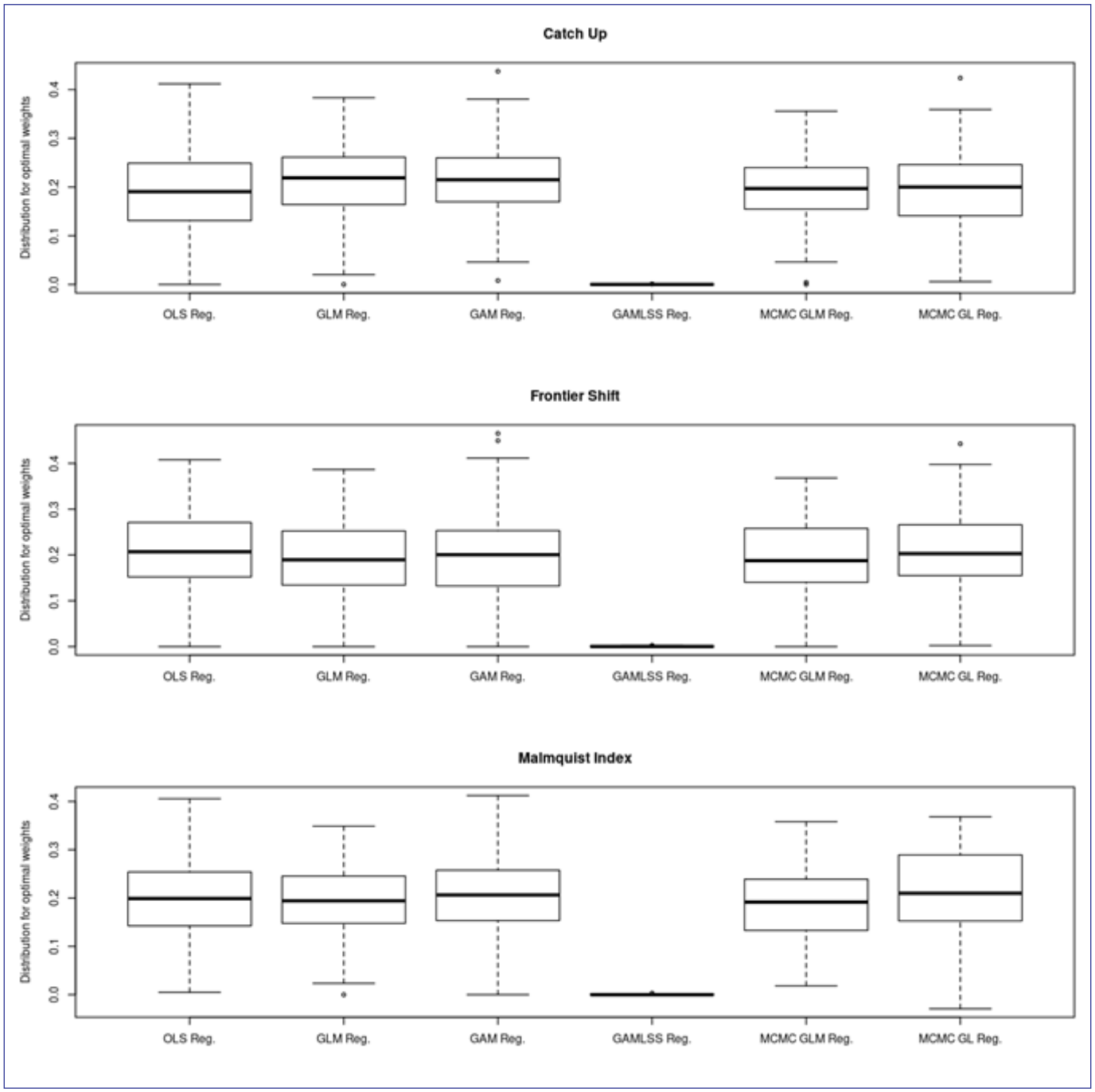
	OLS	GLM	GAM	GAMLSS	MCMC GLMM	MCMC GL
Technical Change	0.1791	0.1675	0.1773	0.1863	0.1780	0.1696
Frontier Shift	0.0472	0.0469	0.0471	0.1110	0.0449	0.0430
Malmquist Index	0.1325	0.1325	0.1301	0.2694	0.1321	0.1241

Source: Elaborated by the authors.

The results for the non-linear stochastic optimization on the residuals of 100 bootstrap regressions according to the OLS, GLM, GAM, GAMLSS, MCMC-GLMM, and MCMC-Gaussian Linear methods are presented in Figure 2 for the MPIs of the different steel companies around the world. The results suggest, with the exception of the GAMLSS regression, almost the same dispersion among the weights assigned to the other 5 regressions. Also interesting to note are the best performances of the OLS and GAM models for the displacement of the frontier and the change of productivity. These results suggest the importance of a combination of different methods not only in terms for removing bias, but also in terms of capturing the benefits of mixing different distribution formats for the prediction of efficiency.

Figure 2

Optimal distribution of weights



Source: Elaborated by the authors.

The results from the bootstrap combined regression for the contextual variable coefficients used to predict the MPIs are presented in Figure 3. Readers should note that if the distribution of the bootstrap coefficients crosses the solid line that marks zero in each graph in Figure 3, the variable should be interpreted as not significant. This is the case for some contextual variables analyzed in the context of the three models, implying that productivity in the steel producers is driven by the economy of various factors such as the change in total productivity and the effects of Technical Change and Frontier Shift. The results regarding the significance and the direction of the impact on the indexes are summarized in Table 2.

Table 2

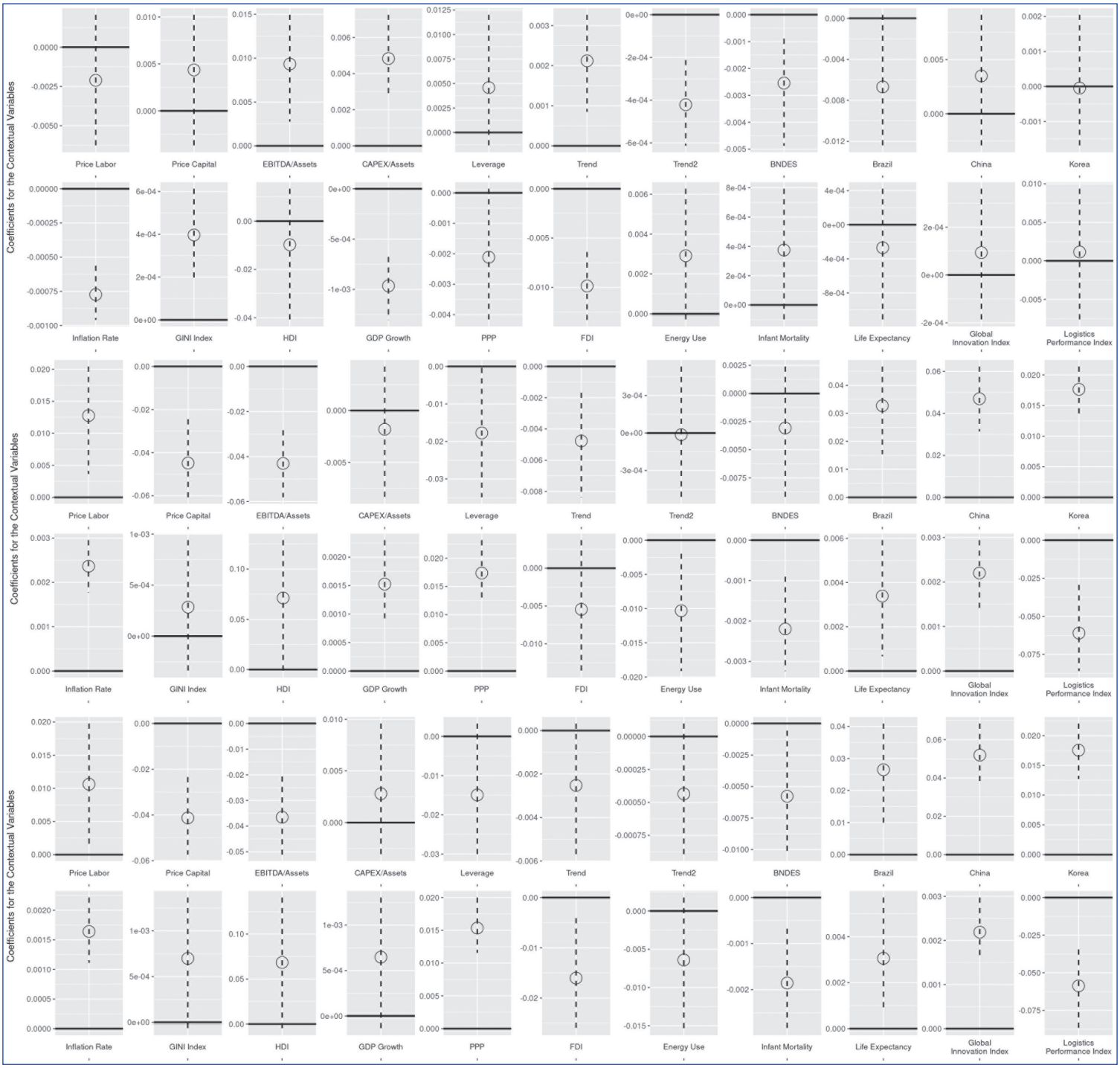
Results of the coefficients from the contextual variables

Variable	Technical Change		Frontier Shift		Malmquist Index	
	Sign	Significant	Sign	Significant	Sign	Significant
Price of labor (LN)	-		+	*	+	*
Cost of capital (LN)	+		-	*	-	*
EBITDA/assets	+	*	-	*	-	*
CAPEX/assets	+	*	-		+	
Leverage	+		-	*	-	
Trend	+	*	-	*	-	
Trend^2	-	*	-		-	
BNDES	-	*	-		-	*
Brazil	-		+	*	+	*
China	+		+	*	+	*
Korea	-		+	*	+	*
Inflation (%)	-	*	+	*	+	*
Gini Index	+	*	+		+	
HDI	-		+		+	
GDP Growth (%)	-	*	+	*	+	
GDP PPP ($)	-		+	*	+	*
FDI ($)	-	*	-		-	*
Energy Use (kg eq. oil *per capita*)	+		-	*	-	
Infant mortality (1,000 births)	+		-	*	-	*
Life expectancy (years)	-		+	*	+	*
Global innovation index	+		+	*	+	*
Logistics performance index	+		-	*	-	*

Source: Elaborated by the authors.

Figure 3

Results of the coefficients for Technical Change (high), Frontier Shift (mean), and Malmquist Index (low)



Source: Elaborated by the authors.

A greater relevance of the Frontier Shift effect can be observed in the definition of the Malmquist index to the extent that the respective coefficients have the same signs for most of the contextual variables. In addition, compared to most of the contextual variables, the significance for the Malmquist index comes from the significance for its respective *Frontier Shift*. The two effects are strengthened in response to the contextual variables BNDES, China, Gini, FDI, and the global innovation index.

As for the Technical Change effect, only 9 contextual variables were considered significant. The positive impact was because of EBITDA/assets (cash generation) and CAPEX/assets (investment) ratios, the short-term trend, and the Gini index. According to the literature review, the results corroborate the expectation as to the positive impact insofar as in the short term a greater volume of investment would enable productive modernization and larger scales of production on the one hand, while the growth of the Gini index, representing an improvement in the distribution of income, reinforces the inductor power represented by the GDP through the incorporation of steel consumption *per capita*. Additionally, in the short term, the greater cash generation can represent greater operational efficiency, providing resources that contribute to the schedule of investments.

As for the variables of negative impact, the long-term trend would corroborate to the inefficient allocation of resources (SUN, DONG, and ZHAO, 2017). The inflationary effect can be interpreted as symmetrical to the Gini index effect, and in fact this effect has been considered negative for the distribution of income. In principle, the negative effect of the growth in GDP and the foreign direct investment (FDI) would be contrary to the expectations regarding the inducer role of the GDP and investment. However, it should be considered that the first, if on the one hand would have an inducer effect, on the other hand it represents an increase in the level of activity that would affect the economy as a whole, opening up space for stronger competition with the allocation of resources and the consequent pressure of costs represented by the inflationary impact. The interpretation of the second would follow this same line of competition for allocation of resources in other productive activities. Additionally, unlike the CAPEX/assets ratio, this index does not fully translate into investment in the expansion and modernization of capacity. In general, portions of this investment have been used to acquire existing assets and portfolio investments (shares on the stock exchange).

As for the research's hypothesis, however, it cannot be corroborated by the results inasmuch as BNDES financing has a negative impact on the Technical Change effect. It should be pointed out that the expectation of this instrument of industrial policy would be precisely to promote the increase of the companies' competitiveness while reducing the gap in relation to the efficient frontier.

But as for the Frontier Shift, its 14 variables showed to be significant. The positive impact would come from the price of labor, the dummies of the countries, the inflation rate, GDP growth, GDP by purchasing power parity (GDP PPP), life expectancy, and global innovation index. This corroborates the expectations with regard to the specificities of the countries and the development indicators with effects on modernization and incorporation of technology. Specifically, the positive impact of the price of labor in a capital-intensive industry can represent an incentive to the commitment of more qualified workers (WANKE, AZAD, BARROS et al., 2016). Furthermore, the growth and level of economic activity would provide new scales of production, allowing for the displacement of the efficiency frontier.

The negative impact from the variables of price of capital, cash generation, indebtedness, trend, energy use, infant mortality, and logistics performance index corroborates some of the expectations discussed in the literature review. Considering the capital-intensive nature of the steel sector, the negative sign of the cost of capital corroborates with the theoretical hypothesis of a negative impact of this cost on the firm's efficiency, as well as the negative impact from the leverage on the indicators of technological frontier may indicate that the financial cost of the indebtedness on the part of the companies in the sample would be related to a worse performance in the generation of financial results, thus impacting the products profit and dividends. In the case of an energy-intensive sector in which various studies emphasize the relevance of energy efficiency, the negative impact of the intensity of using energy would be consistent with the representation of an environment of high energy consumption, thus competing with the steel sector. The negative impact of infant mortality is consistent with greater social development. In turn, the negative impact from the logistics performance index seems to be representing the correlation between the use of logistics and the level of activity. The higher the latter, while keeping constant with the infrastructure available, would cause a worsening in the index. In this sense, highlighting the positive impact from the level of activity on the Frontier Shift represented by the coefficients of the inflation rate, GDP growth, and GDP PPP, the negative impact from the logistics performance index would be consistent.

As for the contextual variable BNDES, this would not be significant for displacing the frontier. This result would be consistent with the expectation from this public policy instrument, which would be toward reducing the technological gap that exists and not for the displacement of the frontier.

The impact from BNDES specifically can also be understood in light of the behavior of the dummy Brazil. It should be pointed out that during the period analyzed, there were not BNDES disbursements in the steel sector neither for all the Brazilian companies (CSN) nor in all the years. The relevance of the dummy Brazil for defining the frontier efficiency would be an indication that, as a whole, Brazilian companies have contributed more to the displacement of the efficiency frontier than for the Technical Change effect. Therefore, for Brazil, the Frontier Shift effect would be more significant, indicating that the financing from BNDES would not be relatively significant for this productive sector.

CONCLUSIONS

The wide use of two-stage DEA models for estimating efficiency frontiers and identifying contextual variables that explain the performance of firms, in particular as regards the various studies on the banking sector, seems to be promising for assessing the impact of development banks on the productive performance of industries. The implications of public policies may indicate a reorientation of the loan transactions from these banks, implying, for example, in the systematization of institutional instruments that focus on the resources according to pre-defined objectives.

No positive impact was identified in this study from the BNDES loans on the efficiency of the firms in the recent period, specifically regarding reducing the efficiency gap through a possible Technical Change effect. However, this study has limitations because it represents a specific sector sample, the steel sector. Complementary studies with a focus on other industrial sectors receiving financing from BNDES may contribute to evaluating the hypothesis proposed.

Furthermore, it should also be noted that the actions of BNDES and other development banks could have an impact on other social objectives (YEYATI, MICCO and PANIZZA, 2007) that are beyond the scope of this article. To broaden this scope, future research should consider the projects financed by BNDES and their respective social impacts.

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