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Corruption, bureaucracy and other institutional failures: the “cancer” of innovation and development

Leonardo A. Rocha
Federal Rural University of the Semi-arid

Maria Ester S. Dal Poz
University of Campinas

Patrícia V.P.S. Lima
Federal University of Ceará

Ahmad S. Khan
Federal University of Ceará

Napiê G. A. Silva
Federal Rural University of the Semi-arid

Abstract

This study analyzes the impact of corruption on the elasticity of R&D investments in sales per worker by firms. In this sense, it built a model of Schumpeterian growth using optimal control theory relating the effects of corruption on demand for R&D. The model results show that corruption negatively affects the R&D demand and long-term rate of technical progress. However, this cost attributes different 'weights' as firms approach the technological frontier. To empirically test this relationship, it was built partial order-□ frontiers on a sample of 2,000 firms from 40 sectors and 46 countries. Interacting efficiency scores with the corruption index, the less-efficient firms are disadvantaged with corruption in relation to the frontier firms. This pattern is observed in the coefficient of elasticity of R&D investments indicating that corruption leads to different costs, 'favoring' the most efficient firms in relation to the most backward firms.

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Contact: Leonardo A. Rocha - leonardoandrocha@yahoo.com.br, Maria Ester S. Dal Poz - ester.dalpoz@fca.unicamp.br, Patrícia V.P.S. Lima - pvpslima@gmail.com, Ahmad S. Khan - saeed@ufc.br, Napiê G. A. Silva - pie@ufersa.edu.br.
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1. INTRODUCTION

Both the economic theory and empirical evidence show that investment in Research and Development (R&D) play an important role to increase productivity in firms and in the development of any economy (Aghion and Howitt, 1992; Aghion and Howitt, 2009). Recent studies, notably Hall and Lerner (2009), Coad (2011), Cappelen, Raknerud and Rybalka (2012) and Hall, Lotti and Mairesse (2013), have shown through empirical evidence the importance of these investments as a fundamental input to innovation.

In addition, the return of these investments is in the long term. This demands a very favorable institutional environment regarding the stability of eventual risks of the activity. This way, a favorable economy depends on arrangements that mainly minimize predatory activities as corruption and its instruments of legitimacy (Wang and You, 2012; Méon and Weil, 2010; Anokhin and Schulze, 2009).

Anokhin and Schulze (2009) have analyzed the link between corruption control and the innovative environment of businesses. The study results show that an environment that highly controls corruption is associated with high levels of innovation and entrepreneurship. Wang and You (2012) focused their analyses on the increase of Chinese firms' sales and showed that China, as a "Paradox of the Eastern Asia", has reported growth much higher than many other emerging economies, despite the high levels of corruption. Some studies refer to this dichotomy on the effects of corruption as two important hypotheses: (1) the hypothesis of "grease the wheels"; and (2) the hypothesis of "sand the wheels" (Méon and Sekkat, 2005; Méon and Weil, 2010).

Therefore, 'reasonable' degrees of corruption can speed up some investment projects that are affected by excessive bureaucracy. Méon and Weil (2010) analyzed the effects of corruption on the productivity of countries, considering the influence of other governance dimensions on this relationship. Conclusions suggest that the hypothesis of "grease the wheels" is supported in countries with poor governance.

Although these results point out conflicts on the understanding about the consequences of corruption and other "institutional failures", few studies (notably Gaviria (2002), Smarzynska and Wei (2002), Batra, Kaufmann and Stone (2003), Hallward-Driemeier, Wallstern and Xu (2004), Asiedu and Freeman (2009) and Wang and You (2012)) analyzed the effects of corruption at microdata level in firms. None of these studies analyzes the influences of corruption on specific investments, like expenditures with R&D, and its link with the businesses' efficiency. This survey believes that both hypotheses are strongly related to differences in efficiency or to the firms' distance from the frontier. That is so because firms farther from the frontier have important limitations, differentiating the 'weight' of corruption perception in relation to the firms on the frontier.

However, measuring the frontier and the firms' distance is not an easy task. The usual techniques of linear regression fail in capturing important traits of a technologically efficient product. The 'best practice' does not necessarily imply 'average practice' because the first does not incorporate aspects related to scale and scope economies (Daraio and Simar, 2007, p. 02).

In this way, to measure the impact of corruption on investments in R&D, efficiency scores were built using the latest non-parametric technique: partial frontier approaches namely order-alpha. This new technique is more robust regarding the presence of outliers and incorporates the concept of quantile to estimate different frontiers. The efficiency score is interacted with a corruption index and investments in R&D for each estimated frontier. As result the different scores give rise to different perceptions on corruption regarding its influence on investments. To less efficient firms, or those farther from the frontier, the impact of corruption is relatively higher against the most efficient firms.

2. THEORETICAL MODEL

2.1. Economic Environment

Firms allot inputs to the production of final goods, according to the production function that is represented by equation (1). Agents have risk-neutral preferences and live only to maximize consumption. Time is considered to be continuous and continuous intermediary inputs between [0,M] that, for convenience, we will assume M=1:

$$Y_t = \int_0^1 (A_{it}L)^{1-\alpha} x_{it}^{\alpha}\, di \;\therefore\; \alpha \in (0,1); \delta \geq 0 \tag{1}$$

The intermediary inputs "x" are measured in industrial processing value, so the economy GDP is measured by the final production less what has been added in manufacture. Therefore, integrating all sectors:

$$PIB_t = Y_t - \int_0^1 x_{it}\, di \tag{2}$$

The price of each input is determined by its demand:

$$p_{it} \equiv \frac{\partial Y_t}{\partial x_{it}} = \alpha (A_{it}L)^{1-\alpha} x_{it}^{\alpha-1} \tag{3}$$

The monopolist firm tries to maximize profits, according to the production of manufactured inputs:

$$\prod_{it} = \underset{x \in X}{\text{máx}} \left\{ p_{it} x_{it} - x_{it} \right\} \tag{4}$$

Replacing in equation (2):

$$PIB_t = Y_t - \alpha^{\frac{2}{1-\alpha}} A_t L = \alpha^{\frac{2}{1-\alpha}} \left(\alpha^{-2} - 1 \right) A_t L \tag{5}$$

Equation (5) shows how the GDP (PIB, in the formula) of a given economy is accumulated over time. Expenditures with in Research and Development increase the probability of success of further innovations, and can be expressed in the following equation:

$$\mu_{it} = \phi n_{it}^{\lambda} \tag{6}$$

According to equation (6), n_{it} corresponds to expenses in research per worker, λ corresponds to the research elasticity (that we assume to be $\lambda \in (0,1)$, according to the Law of Diminishing Returns and ϕ the research productivity that, by notation, is assumed to be small enough to ensure $\mu \in [0,1]$. If innovation ensures better productivity, the technology parameter advances in relation to the lagged period, therefore, the technology process occurs with the mathematical expectation of productivity growth, complying with a given incremental innovation $(\gamma - 1)$:

$$g_{it} \equiv \frac{\dot{A}_{it}}{A_{it}} = E(\gamma - 1) = \phi n_{it}^{\lambda} (\gamma - 1) \tag{7}$$

2.2. Optimum Selection of the Economic Planner

The utility function is represented as follows: $u(c_t) = \frac{{c_t}^{1-\sigma}}{1-\sigma}$. Consumption is ascertained through the ratio between aggregate consumption and stock of workers L. The economy GDP is distributed between consumption and investment, represented by aggregate expenses in research and development (R&D):$PIB_t \geq C_t + N_t$. Considering in units per worker, we have:

$$pib_t \geq c_t + n_t \therefore pib_t \equiv \frac{PIB_t}{L}; c_t \equiv \frac{C_t}{L}; n_t \equiv \frac{N_t}{L} \tag{8}$$

The economic planner aims to maximize the economy well-being, represented by the consumption discounted at a constant rate – ρ –, and the restriction of technology accumulation $(\dot{A}_t = \phi n_{it}^{\lambda} (\gamma - 1) A_t)$:

The Hamiltonian solution of value-current is given according to the required and sufficient conditions of an optimum path:

$$\frac{\partial \mathcal{H}(n_t, A, \beta_A)}{\partial n_t} = 0 \tag{9.a}$$

Euler's equation consists in:

$$\dot{\beta}_A = \rho\beta_A - \frac{\partial\mathcal{H}(n_t,A,\beta_A)}{\partial A_t} \tag{9.b}$$

With the transversality condition:

$$\lim_{t\to\infty} e^{-\rho t}\beta_A A_t = 0 \tag{9.c}$$

Based on these quotes, we can define the long-term conditions (state-stationary) that affect the demand for research resources. Then, $\exists\tilde{n} \in \operatorname{int}(W) \Rightarrow \dot{c}_t = 0$:

$$\boxed{g_t\frac{\varphi\lambda}{\tilde{n}} - \rho = 0 \leftrightarrow \tilde{n} = \left[\frac{\varphi\lambda\phi(\gamma-1)}{\rho}\right]^{\frac{1}{1-\lambda}}} \tag{10.a}$$

$$\frac{\partial\tilde{n}}{\partial\gamma} = \left(\frac{1}{1-\lambda}\right)\left[\frac{\varphi\lambda\phi(\gamma-1)}{\rho}\right]^{\frac{\lambda}{1-\lambda}}\left(\frac{\varphi\lambda\phi}{\rho}\right) \geq 0 \tag{10.b}$$

According to equation (10.b), the highest size of innovation, highest incentive to allot resources for long-term research. This seems to be a tautological result, but it is not as simple as it seems. The innovation size depends on several factors that can result or not from the firms' decisions.

2.3. The effects of corruption and bureaucracy on the decisions about investments

The institution's poor credibility bound to the poor execution of some contracts and the slowness of justice may lead entrepreneurs to appropriate resources on behalf of liquidity, rather than investing in long-term projects. The natural consequence of this inertia is the restriction of efforts in innovation and of the technology path of firms, compromising the economy development process (Lambsdorff, 2003; 2007; Hacek, Kukovic and Brezovsek, 2013). Through this exposure, the distribution of resources is limited by the corruption action that effectively reduces investments in R&D:

$$pib_t - \theta(\omega,\varrho,\Theta)n_t \geq c_t + n_t \therefore pib_t; \frac{\partial\theta(\omega,\varrho,\Theta)}{\partial\omega} \geq 0; \frac{\partial\theta(\omega,\varrho,\Theta)}{\partial\varrho} \leq 0 \tag{11}$$

According to the relation (11), corruption absorbs an important share of investments ($\theta \in (0,1)$) that would be invested in innovation activities if public officers did not expropriate resources. The higher the parameter θ, higher the appropriation of investments as a result of corruption. Corruption depends on important institutional aspects such as bureaucracy (ω), the judiciary power efficiency (ϱ), cultural and historical factors (Θ), among others. Therefore, the problem solution is reformulated as follows:

$$\underset{n_t\geq 0}{\text{máx}}\, W[n_t,\beta_A] \stackrel{\text{def}}{=} \int_0^{+\infty} e^{-\rho t}\,u(c_t)dt;\ s.a.\{\dot{A}_t = \phi n_t^{\lambda}(\gamma-1)A_t$$

Then, $\exists\tilde{n} \in \operatorname{int}(W) \Rightarrow \dot{c}_t = 0$, implying the final solution adjusted by the presence of corruption:

$$\boxed{g_t\frac{\varphi\lambda}{(1+\theta(\omega,\varrho,\Theta))\tilde{n}} - \rho = 0 \leftrightarrow \tilde{n} = \left[\frac{\varphi\lambda\phi(\gamma-1)}{(1+\theta(\omega,\varrho,\Theta))\rho}\right]^{\frac{1}{1-\lambda}}} \tag{12}$$

The long-term solution to the demand for investments in R&D inversely depends on the share of resources that was appropriated. Therefore, the excessive bureaucracy showed by an increase in ω implies more incentive to corruption, rising θ and reducing the levels of investment in long-term R&D. The effect of corruption on the demand for long-term investment is observed in the partial derivative:

$$\frac{\partial\tilde{n}}{\partial\theta(\omega,\varrho,\Theta)} = -\left(\frac{1}{1-\lambda}\right)\left[\frac{\varphi\lambda\phi(\gamma-1)}{(1+\theta(\omega,\varrho,\Theta))\rho}\right]^{\frac{\lambda}{1-\lambda}}\left(\frac{\varphi\lambda\phi(\gamma-1)}{(1+\theta(\omega,\varrho,\Theta))^2\rho}\right) \leq 0 \tag{13}$$

The solution in (13) shows the inverse relation between corruption and the demand for investments in long-term research. The judiciary power efficiency has an effect of penalty on these activities, reducing incentives to corruption and, then, to the appropriation of resources, fostering the demand for long-term investments in R&D. Recent studies have pointed out this conclusion, notably Wang and You (2012), Hacek, Kukovic and Brezovsek (2013) and Schumacher (2013).

2.4. Growth, technical progress and corruption

Therefore, the sector growth rate is governed by the weighed growth of different inputs and the technology advances:

$$\tilde{g}_{it}^{y} = (1-\alpha)\tilde{g}_{it} + (\alpha)\tilde{g}_{it}^{x} \tag{14}$$

Without losing generality, growth rate will be tuned out from the intermediary inputs ($\tilde{g}_{it}^{x} = 0$). Therefore, $\tilde{g}_{it}^{y} = (1-\alpha)\left[\left(\phi(\gamma-1)\right)^{\frac{1}{1-\lambda}}\left(\left[\frac{\varphi\lambda}{(1+\theta(\omega,\varrho,\Theta))\rho}\right]^{\frac{\lambda}{1-\lambda}}\right)\right]$. To check the effect of corruption on the growth rate, the partial derivative is applied using the "chain rule":

$$\frac{\partial \tilde{g}_{it}^{y}}{\partial \theta(\omega,\varrho,\Theta)} = (1-\alpha)\left[\underbrace{\left(\frac{\partial \tilde{g}_{it}}{\partial \tilde{n}_{it}}\right)}_{\geq 0} \cdot \underbrace{\left(\frac{\partial \tilde{n}_{it}}{\partial \theta(\omega,\varrho,\Theta)}\right)}_{\leq 0}\right] \leq 0 \tag{15}$$

The first part of the derivative in (16) is clearly positive. However, the second part is negative and measures the primary impact of corruption on the reduction of resources in research, with impacts on a second step in the rate of technical progress and growth. This intuitive result shows that persistence of resources appropriation directly damages the growth rate of firms, sectors and of the economy in the long-term. Although the average effect of the predatory activity is clearly negative, important issues like the firm size, kind of industry, firm's efficiency, among others, could also restrain the impact size on different enterprises.

2.5. Other institutional aspects of corruption

Throughout history, institutional changes and their relations with property rights have been an important determinant of economic growth. According to Davis and North (1971) and North (1990), such changes are feasible in that as the benefit to a group of individuals outweighs the potential costs of change. More open societies experience social changes in time that reflect more dynamic institutions and that stimulate more productive activities. These institutional designs imply rewarding more the creation and diffusion of ideas, punishing predatory activities that repress (Acemoglu and Robinson, 2012). These historical-cultural aspects may represent an important determinant of institutional dynamics, explaining the trajectory of corruption among different economies (Acemoglu, Johnson and Robinson, 2001).

However, these institutional arrangements are not static, and although the dynamics are relative between economies, it does not imply that countries with high levels of corruption are bound to fail in the future. In this regard, Mokyr (2018) indicates that the world scenario in the post-Industrial Revolution shows a growth in the world marked by gains in trade and factor mobility, better and more integrated markets and efficient allocations, factors especially associated with better institutions. However, institutional developments in certain regions of Europe were also vulnerable to political shocks at the time. In this case, often unintentional victims of dynastic and religious wars, the true nature of the political conflict involved the extraction of wealth, control over trade routes and natural resources, the latter quite profitable to the standards of the time. This showed a predatory behavior of income, whose predatory nations had a similar behavioral pattern, involving confiscatory taxes, expropriating wealth, sale of monopolies, and repudiating debts. The absence of institutional arrangements for development has helped to explain how certain economies have evolved peacefully alongside corruption, bureaucratic institutions, deficient rule and law, and autocratic regimes, concentrating resources on a compulsory basis for local rulers and elites. Such facts explain why the industrial revolution occurred in England rather than China, which administered a technological standard far superior to the time. However, predatory institutions, which repressed the generation and diffusion of new ideas, have limited technical progress over the years, although this reality will change recently with the rapid growth observed in the post-Second World War in Asia (Amsden, 2001).

3. EMPIRICAL MODELING

3.1. Definition of Sample and Operationalization of Variables

To measure the influence of innovative efforts on the corporations' performance, we have adopted the *The 2013 EU Industrial R&D Investment Scoreboard* database (EUROPEAN COMMISSION, 2013). This is an annual report that shows the ranking of corporations (top investors on innovation in the world) with highest volume of expenses in Research & Development (R&D) distributed among 40 sectors in 46 countries of the world. Additionally to this variable, information includes sales volume (€ million), number of workers, expenses with capital (€ million), profitability, in addition to measures of growth. The sample size corresponded to 2,000 firms. Scoreboard data cover more than 90% of total R&D expenditure in the world.

3.2. Estimating the Technological Frontier

An alternative approach proposed by Aragon, Daouia and Thomas-Agnan (2005) shows that the concept of conditional quantiles function is more robust in the presence of two problems, typical to the economic series: (i) outliers; and, (ii) 'curse of dimensionality'. The quantiles method is traditionally known for being more robust regarding the presence of outliers (Koenker and Bassett, 1978; Koenker and Hallock, 2001; Koenker, 2005). This technique so-called by partial order-alpha frontier.

3.3. Econometric Methodology

To analyze the impacts of investments in R&D on sales per the firms' workers, given the existence of corruption in different countries, the following equation was estimated:

ME.1

$$ln\left(\frac{Y}{L}\right)_{ijc} = \beta_0 + \beta_1 \cdot CC_c + \beta_2 \cdot ln\left(\frac{R\&D}{L}\right)_{ijc} + \beta_3 \cdot \tilde{\lambda}_\alpha(x,y)_{ijc} \cdot CC_c \cdot ln\left(\frac{R\&D}{L}\right)_{ijc} + \mu_j + \delta_c + \varepsilon_{ijc}$$

ME.2

$$ln\left(\frac{Y}{L}\right)_{ijc} = \beta_0 + \beta_1 \cdot CC_c + \beta_2 \cdot ln\left(\frac{R\&D}{L}\right)_{ijc} + \beta_3 \cdot \tilde{\lambda}_\alpha(x,y)_{ijc} \cdot CC_c + \mu_j + \delta_c + \varepsilon_{ijc}$$

According to the equation ME.1 the variables $\frac{Y}{L}, CC, \frac{R\&D}{L}$ represent, respectively, sales per work, corruption index in each country and investments in R&D per worker made by firms 'i', in sector 'j' and in the country 'c'. Regarding the corruption indicator, it was extracted from *The Worldwide Governance Indicators* (WGI) compiled by the World Bank (Kaufmann, Kraay and Mastruzzi, 2010). The calculated indicator was standardized in the interval $CC_c \in (0,1)$ so that the higher the value (closer to 1), higher the perception that public power is exercised to expropriate private gains. Therefore, institutions are perceived as more corrupted.

Regard the efficiency parameter $\tilde{\lambda}_\alpha(x,y)_{ijc}$, it in fact reflects the relative distance of each firm from the frontier, matching the required inputs to get the maximum of product. Table 1 summarizes the input-output combination in the estimate of efficiency scores.

Table 1: *Definition of variables to calculate the efficiency scores*

Variables	Variables definition	
Y	Total sales	
L	Number of workers	
K	*Capex*: capital expenditure	
	Dividing of variables to calculate scores	
	Output	**Input**
	Y	L
	-	K

Source: Own elaboration.

Based on the definition of variables in Table 1, one frontier was calculated by sector, totaling 40 frontiers. To each sector group, five quantiles (25%, 50%, 75%, 95% and 100%, where this last is the final FDH frontier) were divided, and each quantile will be estimated in a representative frontier. Therefore, the total number of frontiers to be estimated is *5x40 = 200* frontiers of efficiency in the sample.

In addition to the model, μ_j, δ_c represent the sets of fixed effects related to the characteristics of factors of heterogeneity observed between sectors and to the countries, respectively, being necessary as control in the estimation process. Finally, there is the stochastic error term ε_{ijc} that corresponds to all the remainder common factors out of the statistical control: $\varepsilon_{ijc} \sim N(0, \sigma_\varepsilon^2)$ to every i, j, c.

Therefore, applying the traditional methodology to calculate the elasticity of investments in R&D on sales per worker, we have:

$$\hat{\epsilon}_{R\&D} \equiv \frac{\partial ln\left(\frac{Y}{L}\right)_{ijc}}{\partial ln\left(\frac{R\&D}{L}\right)_{ijc}} = \hat{\beta}_2 + \hat{\beta}_3 \cdot \tilde{\lambda}_\alpha(x,y)_{ijc} \cdot CC_c \qquad \text{ME.1a}$$

$$\hat{\epsilon}_{CC} \equiv \frac{\partial ln\left(\frac{Y}{L}\right)_{ijc}}{\partial CC_c} = \hat{\beta}_1 + \hat{\beta}_3 \cdot \tilde{\lambda}_\alpha(x,y)_{ijc} \qquad \text{ME.2a}$$

According to the ME.1a equation, the final elasticity depends on two components: (1) the direct effect of investment on the firms' performance; and, (2) the appropriative factor of corruption.

3.4. Estimation Method

Systematic movements in the stochastic error can be followed by changes in some regressors (such as corruption and R&D), leading to an endogeneity problem associated with an error of specification in the model. This likely result points out precariousness in the traditional methodology of Ordinary Least Squares (OLS) when endogeneity are not controlled.

Powers of geopolitical nature strongly influence the decisions on investments in R&D. This 'vector of influence' builds a correlation between the expected results of investments and future investments, leading to covariance different from zero between regressors, and to stochastic disturbance. This influence pattern occurs because as the firm gets closer to the frontier, more R&D resources are required to sustain technology convergence, building significant association between investments in different non-observable factors such as: management, strategic organization forms, incentives, etc. (Hall, Lotti and Mairesse, 2013). This association presents a differentiated pattern near the frontier in relation to the farther firms, due to different research costs of opportunity (Aghion and Howitt, 2009). In this sense, corruption perception can be strongly influenced by the excessive bureaucracy that encourages a good share of firms to allot significant shares of their resources to speed up their investment projects. Moreover, the firms' profitability may induce corruption as a potential source of resources to be appropriated, strengthening the link between performance and the 'predatory activity' (Lambsdorff, 2004; 2007).

This violation of the assumption provides the MQO methodology with fixed effects an inconsistent one, leading to the need for an alternative approach named Generalized Moments Method – or GMM. Table 2 shows a summary of the variables selected in the main model and the respective instruments to be used. The selected instruments will be tested according to the statistics test: (1) instrumental validity - J-Hansen Test; and (2) instrumental relevance – Kleibergen and Paap's (2006) post test.

***Table 2*:** Definition of variables in the econometric model.

Variables	Acronym	Reference
Sales per worker	Y/L	Hall (2002); Hall & Lerner (2009)
Invest. R&D per worker	R&D/L	Aghion & Howitt (2009); Coad (2011)
Corruption Index	CC	Kaufmann, Kraay & Mastruzzi (2013)
Order-α Efficiency Score	$\lambda_\alpha(x,y)$	Simar & Wilson (2013)
Instruments	**Acronym**	**Reference**
Bureaucracy Index	GE	Kaufmann, Kraay & Mastruzzi (2013)
Profit increase rate (last 3 years)	$G_{profit\text{-}3years}$	Hall, Lotti & Mairesse (2013)
Profits level	π	Hall, Lotti & Mairesse (2013)
Instrumented Variables (Acronyms)	**Acronym**	**Reference**
$\ln(R\&D/L)*CC*\lambda_\alpha(x,y)$	-	-
$CC*\lambda_\alpha(x,y)$	-	-
CC	-	Kaufmann, Kraay & Mastruzzi (2013)

Source: Own elaboration.

4. ANALYSIS OF RESULTS

4.1. General Results of the Econometric Model

The first estimates of the model, disregarding only the effect of corruption interaction and the efficiency score on investments in R&D - ME.2 (Table 3). According to the table results, the corruption effect - depending on the different levels of efficiency of the firms - presents negative and significant expected impact on all conditional quantiles (1%).

An important highlight is the gradual reduction of the effect of interaction with the efficiency score (Fig 1). This pattern suggests relatively higher costs to firms with low-performance in the lower quantiles.

The total effect of corruption on the performance reduction is measured by the elasticity coefficient (ME.2a): $\frac{\partial ln\left(\frac{Y}{L}\right)_{ijc}}{\partial CC_c} = \hat{\beta}_1 + \hat{\beta}_3 \cdot \tilde{\lambda}_\alpha(x,y)_{ijc}$. Considering the 25% quantile, the impact of corruption to the firms on the frontier has a negative effect, considering that the partial parameter, although positive (3.065), is lower than the interaction parameter (-10.96). Therefore, for inefficient firms scoring above one unit ($\tilde{\lambda}_\alpha(x,y) > 1$) the impact of corruption is always negative on the reduction of the firm's productivity. Taking the values in the vicinities of the frontier to the next quantiles ($\lim \tilde{\lambda}_\alpha(x,y) \to 1$), the coefficient of elasticity changes from -7.90 (25% quantile) to -4.68 (50% quantile), -1.45 (75% quantile), 2.46 (95% quantile) and 3.44 (100% quantile or final FDH frontier).

One can conclude that in lower quantiles (25%-50%) corruption presents a common effect of reducing productivity of firms, regardless if on the frontier or inefficient. This pattern changes as we displace the frontier of low-performance towards the total frontier, where the effect to the frontier firms present a positive pattern with the presence of corruption. These characteristic evidences that the 'grease the wheels' effect is more likely to firms with high-efficiency, notable observed on the upper quantiles or for super-efficient corporations (outlier's).

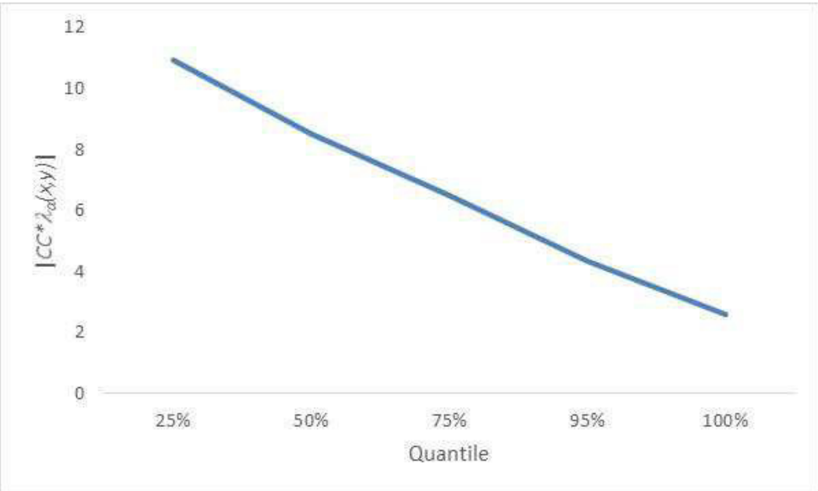
Table 3: Results of the econometric model - ME.2

VARIABLES	GMM Method - Dependent Variable: ln(Y/L)				
	(1) 25% Quantile	(2) 50% Quantile	(3) 75% Quantile	(4) 95% Quantile	(5) FDH
CC	3.065***	3.849***	5.062***	6.788***	6.056***
	(0.418)	(0.473)	(0.642)	(0.878)	(1.028)
ln(R&D/L)	0.274***	0.237***	0.197***	0.184***	0.175***
	(0.0282)	(0.0273)	(0.0281)	(0.0297)	(0.0294)
$CC*\lambda_{25}(x,y)$	-10.96***				
	(1.007)				
$CC*\lambda_{50}(x,y)$		-8.526***			
		(0.781)			
$CC*\lambda_{75}(x,y)$			-6.514***		
			(0.679)		
$CC*\lambda_{95}(x,y)$				-4.332***	
				(0.494)	
$CC*\lambda_{FDH}(x,y)$					-2.616***
					(0.486)
Constante	-0.151	-0.381***	-0.662***	-0.867***	-0.805***
	(0.144)	(0.142)	(0.153)	(0.172)	(0.135)
Firms sample	2,000	2,000	2,000	2,000	2,000
Kleibergen-Paap Test	189.958***	215.329***	178.083***	113.504***	13.955***
J-Hansen Test	0.072	0.150	0.170	0.462	0.752
Heteroscedasticity test	114.105***	120.476***	136.592***	67.601***	37.624***
Fixed effects - Country	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Fixed effects - Sector	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Source: Own elaboration.

Note: Asterisks represent the respective levels of significance p<0.01, ** p<0.05, * p<0.1. Standard error estimates were corrected by the Bootstrap Method using B=400 as the replications number. The instrumented variables correspond to the corruption index and index interacted with the efficiency score, *CC* and $CC*\lambda_{\alpha}(x,y)$.

Fig 1: Effect of 'Corruption x Efficiency Score' by quantile.



Source: Own elaboration based on the results of the model.

The J-Hansen statistic did not reject the null hypothesis of valid to instruments. The Kleibergen-Paap's langrage multiplier test rejects the null hypothesis of instruments being not related to regressors, presenting strong statistic strength (rejection of null hypothesis at 1% level). This standard was observed for all conditional quantiles. Regarding the heteroscedasticity tests, in all conditional quantiles statistics rejected the null hypothesis of homoscedastic variance, demanding the correction of standard error estimate using the bootstrap method.

The parameter of the 'corruption control' variable presented positive and significant sign on quantiles 25%-95%, all significant at 1% (Table 4).

Table 4: Results of the econometric model - ME.1

VARIABLES	**GMM Method - Dependent Variable: ln(Y/L)**				
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
	25% Quantile	**50% Quantile**	**75% Quantile**	**95% Quantile**	**FDH**
CC	1.951***	2.542***	3.893***	10.47***	-2.738
	(0.303)	(0.323)	(0.582)	(2.782)	(11.17)
ln(R&D/L)	0.476***	0.454***	0.430***	0.401***	0.382
	(0.0248)	(0.0239)	(0.0237)	(0.0429)	(0.292)
$CC*\lambda_{25}(x,y)*ln(R\&D/L)$	-2.004***				
	(0.164)				
$CC*\lambda_{50}(x,y)*ln(R\&D/L)$		-1.746***			
		(0.145)			
$CC*\lambda_{75}(x,y)*ln(R\&D/L)$			-1.572***		
			(0.179)		
$CC*\lambda_{95}(x,y)*ln(R\&D/L)$				-1.849***	
				(0.446)	
$CC*\lambda_{FDH}(x,y)*ln(R\&D/L)$					0.412
					(1.423)
Constante	2.024***	1.899***	1.849***	1.299***	1.229
	(0.225)	(0.230)	(0.242)	(0.413)	(1.852)
Firms sample	2,000	2,000	2,000	2,000	2,000
Kleibergen-Paap Test	177.605***	162.304***	72.330***	15.641***	1.089
J-Hansen Test	0.684	0.635	0.217	0.635	2.975*
Heteroscedasticity test	55.241***	62.235***	39.559**	16.9642***	1.348
Fixed effects - Country	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Fixed effects - Sector	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Source: Own elaboration.

Note: Asterisks represent the respective levels of significance p<0.01, ** p<0.05, * p<0.1. Standard error estimates were corrected by the Bootstrap Method using B=400 as the replications number. The instrumented variables correspond to the corruption index and investments in R&D interacted with the corruption index and efficiency score, *CC* and $CC*\lambda_{\alpha}(x,y))*ln(R\&D/L)$.

Just like in the previous table, the estimated parameters by each quantile presented ascending tendency, so the positive effect of perception increases as partial frontiers are displaced from the lowest quantiles towards the total frontier. Although the total frontier presents a negative parameter, this was not significant at the maximum level of 10%.

The parameter of the variable ln(R&D/L) showed positive and significant value in virtually all quantiles, except for the total quantile (100% of score by FDH). Moreover, there was a slight variation between the estimated parameters, comparing the variation between 25%-95% quantiles with a reduction of about 16%.

The total effect of corruption on investments in R&D is captured by the elasticity coefficient (ME.1a): $\hat{\epsilon}_{R\&D} = \hat{\beta}_2 + \hat{\beta}_3 \cdot \tilde{\lambda}_\alpha(x,y)_{ijc} \cdot CC_c$. Considering the efficiency scores to the 25%-95% partial frontiers, respectively, the partial elasticity levels correspond to $\hat{\epsilon}_{R\&D}^{25\%} = 0{,}42 - 2 \cdot CC_c$; $\hat{\epsilon}_{R\&D}^{50\%} = 0{,}45 - 1{,}75 \cdot CC_c$; $\hat{\epsilon}_{R\&D}^{75\%} = 0{,}43 - 1{,}57 \cdot CC_c$; $\hat{\epsilon}_{R\&D}^{95\%} = 0{,}40 - 1{,}85 \cdot CC_c$. Therefore, the cost associated with corruption is gradually reduced between the 25%-75% quantiles, with slight increase in the 95% quantile. This way, to the fully-efficient firms the perceptive cost of corruption reduces as the partial frontiers converge to the total frontier (100% quantile or FDH score). This effect is significant at 1% level and is not significant only on total frontier.

This aspect shows that one single frontier may lead to biased scores that reflect, in the background, on the statistical non-significance when we weigh the corruption perception by the firm's degree of efficiency. In this sense, the method through partial frontiers generates a more detailed view on efficiency between firms, capturing significant relations between corruption and investments, as we build different efficiency scores using partial frontier.

It is also more evident in the statistics of validity and relevance of instruments. On the conditional quartiles of 25%-95% the respective statistics do not reject the hypothesis of valid and relevant instruments (Kleibergen-Paap's Test significant at 1% and J-Hansen non-significant at 10%). These statistics fail on the total frontier, showing the potential influence of super-efficient firms (outliers) on the definition of the score to the remainder firms.

4.2. Nonlinear effects of corruption

To capture the nonlinear effects of corruption, as suggested in recent literature, corruption index square was added to model (Table 5). According to the results, the inclusion of variable CC^2 reduced the direct impact of corruption on firm performance (CC). However, the estimated parameters did not show levels of statistical significance. In addition, the parameters of the variable "CC corruption index" presented an increasing pattern along the quantile scores, similar to the previous tables (only the 25% quantile score was not significant at the 10% level).

The parameters of the variable ln(R&D/L) presented statistical significance at the 1% level in all the estimated models. In addition, the parameters showed a decreasing pattern in the value along the quantum scores, following the same pattern in the previous tables.

Regarding the parameters associated to corruption interacted with the quantum efficiency score, the estimates presented statistical significance at the 1% level in all columns. The evolution of the parameters indicates that in the lower quantile scores, the cost of corruption becomes greater, reducing as the partial frontier converges to the FDH frontier. This heterogeneous pattern of the relative cost of corruption, proves to be similar with previous models. Thus, the inclusion of the quadratic variable (CC^2) did not show influence on the evolution pattern of the parameters according to the different quantum scores. However, the lack of significance may reveal that the nonlinear effect of corruption can be affected by firm efficiency, at least by considering the sample of the largest innovation investors. This may suggest that 'optimal levels' of corruption are not observed under particular conditions, especially in innovative environments. As R&D investments depend on favorable institutional conditions, potential benefits from corruption are nullified over the long run, deteriorating the innovative environment and reducing the demand for R&D investments.

Table 5: Results of the econometric model – nonlinear effects of corruption

VARIABLES	GMM Method - Dependent Variable: ln(Y/L)				
	(1) 25% Quantile	(2) 50% Quantile	(3) 75% Quantile	(4) 95% Quantile	(5) FDH
CC	0.963	1.528***	1.587***	1.743***	3.108***
	(0.673)	(0.593)	(0.540)	(0.659)	(1.033)
CC^2	0.676	-0.0971	0.408	1.944	-0.0581
	(1.365)	(1.140)	(0.983)	(1.415)	(1.391)
ln(R&D/L)	0.435***	0.408***	0.384***	0.348***	0.200***
	(0.0233)	(0.0225)	(0.0219)	(0.0247)	(0.0408)
$CC*\lambda_{25}(x,y)$	-4.700***				
	(0.486)				
$CC*\lambda_{50}(x,y)$		-3.561***			
		(0.353)			
$CC*\lambda_{75}(x,y)$			-2.633***		
			(0.259)		
$CC*\lambda_{95}(x,y)$				-1.913***	
				(0.206)	
$CC*\lambda_{FDH}(x,y)$					-1.608***
					(0.396)
Constant	0.314	0.189	0.193	0.430	-0.590**
	(0.237)	(0.206)	(0.197)	(0.343)	(0.268)
Firms sample	2,000	2,000	2,000	2,000	2,000
Kleibergen-Paap Test	189.613***	215.718***	177.123***	111.989***	13.955***
J-Hansen Test	0.079	0.149	0.176	0.504	0.753
Heteroscedasticity test	113.307***	120.345***	136.120***	66.750***	17.760
Fixed effects - Country	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Fixed effects - Sector	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**

Source: Own elaboration.

Note: Asterisks represent the respective levels of significance ***p<0.01, ** p<0.05, * p<0.1. Standard error estimates were corrected by the Bootstrap Method using B=400 as the replications number. The instrumented variables correspond to the corruption index, corruption index square and index interacted with the efficiency score, CC, CC^2 and $CC*\lambda_{\alpha}(x,y)$. The instruments consisted of bureaucracy index, bureaucracy index square, profit increase rate (last 3 years) and profits level.

4.3Discussion with recent surveys

The results presented showed that in low-performance partial frontiers, i.e., those in the lowest quantiles and below the median, corruption cost is higher when compared to the high-performance firms (upper quantiles). Recently, Asiedu and Freeman (2009) found significant results of corruption on the growth of investments in companies from transition countries. According to them, "*for Transition countries, corruption is the most important determinant of investment.*" (p.200).

The mean aspect captured by the traditional regressions 'hides' important differences that are perceived at the scale and scope level. These differences may lead to inaccurate results that are overestimated when we include different firms (low and high performance) (Batra, Kaufmann and Stone, 2003). Recent surveys, notably Wang and You (2012), Wang (2012) and Jiang and Nie (2014) also highlight different results of corruption depending on the different levels of firms. In the authors' results, low and high performance may be associated with efficiency factors, which were not properly addressed in their research.

4.4. Effects and implications for anti-corruption policy

Dixit (2015, p.S26) states that "*a bribe acts as a tax on business, an uncertain and inefficient tax that reduces the incentive to invest and innovate*." Thus, corruption has an impact on reducing future prospects of profitability and growth, considering the business environment as a whole. This indicates that, firms acting rationally for their own benefit at the expense of financing corruption, compromise the competitive environment, leading to losses in the economic system as a whole. This rescues the famous 'prisoner's dilemma', that is, individually rational choices of favored firms can lead to a collectively bad outcome. In this vein, coordinated action among economic agents leading to a collective effort towards an anti-corruption agenda, together with political leaders, results in collectively larger outcomes, especially in the long run (see also Lambsdorff, 2007).

Acemoglu, Aghion and Zilibotti (2006) analyze the impact of strategies based on innovation and imitation by firms, according to their technological position in relation to the frontier. Firms furthest from the frontier are encouraged to adopt business strategies based on the execution of investments that increase their absorptive capacity in implementing technologies of the world-wide frontier. As the firm converges to the frontier, the selection of investment projects based on innovation becomes more important to underpin the convergence process. Under adverse conditions, the persistence of strategies based on technology transfer, to the detriment of innovation, can drive economies into a non-convergence trap. In this case, the late change has long-term consequences for growth, since the economy as a whole fails to take advantage of the best innovation opportunities, generating inefficient results collectively. Thus, persistence with long-term protectionist measures in development, generate surplus profits that are no longer used to finance innovation, becoming important 'bribe funds' to maintain economic privileges. According to Acemoglu, Aghion and Zilibotti (2006, pp.66-67), "*(...) follows because capitalists make greater profits with low competition and have more funds to bribe politicians. This formalizes the idea that, once capitalists become economically more powerful, they also become politically more influential and consequently more likely to secure the policy that they prefer.*".

According to the findings of the present research, the relative cost of corruption at the lower part boundary may be an important indication to the contributions Acemoglu, Aghion and Zilibotti (2006). This is due to the 'weight' of corruption being more onerous to the more inefficient and efficient firms with low dominance (in the case of the quantum partial frontier, efficient frontier-alpha firms are likely to (1-alpha) be 'dominated' by firms more efficient). The cost of corruption tends to reduce the return on investment, through the elasticity obtained, signaling to non-competitive strategies and penalizing innovation. In the long run, the persistence of a highly corrupt scenario can 'stifle' major innovation efforts and is therefore more burdensome for the economies furthest beyond the technological frontier.

The contribution of Acemoglu, Aghion and Zilibotti (2006) helps explain why the quadratic term of corruption did not prove significant to the model. While investments in technology transfer can benefit from corrupt practices, in the long run investment in R & D is seriously affected, limiting a significant portion of the firm's technological trajectory. According to the authors, the rent-shield effect overcomes the natural appropriateness of the return of innovation: profits retained in a non-competitive way create protection mechanisms preventing the entry of new firms more efficient, jeopardizing innovation in an aggregated way. In the long term, persistence of corruption can drive economies into a non-convergence trap, limiting technological progress and growth (see Aghion et al., 2016).

The heterogeneous effects of corruption are also adequately portrayed by Assiotis and Sylwester (2014). Although corruption has a clear negative effect on growth, its reduction is associated with greater growth in economies with more authoritarian regimes and low democracy. Thus, the results indicate that the reduction of corruption in the most authoritarian economies produces superior benefits over economies with larger democratic regimes, contrary to the grease the wheels hypothesis (see similar contributions in Assiotis and Sylwester, 2014).

The results of the present research are consistent with the findings of Assiotis and Sylwester (2014) and Aghion, Alesina and Trebbi (2007). Aghion, Alesina and Trebbi (2007) demonstrated that democracy has a positive effect on growth, however, heterogeneous among economies. The further away from the technological frontier the economy is, the less the effect of democracy on growth. The results suggest that barriers to entry and transaction costs may explain the low growth in economies farthest from the border, so that gains from democratic regimes can be offset if economies do not approach the border. Thus, the 'distance to frontier' effect can help explain how different institutions and their arrangements can impact heterogeneously, explaining how certain economies grow more or less in similar institutional regimes.

In the perspective of a reform agenda, measures that facilitate trade openness, promoting competition and the prize for innovation, can accelerate pro-democratic institutional arrangements, facilitating the entry and exit of efficient / inefficient firms by stimulating innovation and progress (Aghion and Griffith, 2006; Aghion and Howitt, 2009). Such measures have a strong impact on the incentive structure, transferring the strategies that protect investments (*rent-shield effect*) to innovative activities (Aghion, Howitt and Prantl, 2015).

Moreover, a punitive structure on the predatory practices of income can contribute to greater transparency of institutions (Dixit, 2016). Recent corruption scandals in Latin America (Car Wash Operation in Brazil, 'K-money road' in Argentina, Reficar case in Colombia, Panama Papers, etc.) and other countries have been pointing to short-term costs in the economic system once that corruption can behave in a more structural way. However, such costs can constitute an important advance in the technological trajectory of the firms as a whole, transferring the award of corruption to innovation.

5. CONCLUDING REMARKS

This study analyzed the effects of corruption on sales per worker of firms in different countries, incorporating the firms' degree of efficiency as weighing factor in the corruption perception. Interacting the efficiency score or distance from frontier with a corruption index and the investments in R&D, the partial elasticity coefficient of investment is negatively affected by corruption.

Results showed that for firms farther from the frontier, the weight of corruption in the reduction of impact of investments in R&D is significantly higher in comparison to the frontier firms, and can be positive to super-efficient firms.

To improve the robustness of the research, other measures of corruption are important and need to be worked out to the model. As a recent contribution to this topic, Assiotis (2012) verifies the relationship between corruption and income, through the three main measures used in the literature: (1) measure of corruption used by Political Risk Services; (2) World Bank's World Governance Indicators (WGI) Control of Corruption index; (3) Corruption Perception Index (CPI) compiled from Transparency International. The three measures employed in the study signaled a lack of relationship between 'corruption versus income' as the model controls important historical factors that shape institutions over time. The results do not necessarily state that there is no corruption in high-income economies, nor that the increase in income is not associated with a reduction in corruption. In contrast, institutional historical factors can more accurately measure the dynamics of corruption, converging to important findings as in Acemoglu, Johnson and Robinson (2001) and Acemoglu and Robinson (2012). Future research, expanding these aspects to the empirical model can offer an important understanding to the subject, although they were superficially treated in the theoretical model. In addition, alternative measures of corruption can improve the robustness of the empirical model, verifying if the presented results are sustained for other variables.

Few studies evaluated the influence of corruption at firms' microdata level, notably Batra, Kaufmann and Stone (2003), Gaviria (2002), Smarzynska and Wei (2002), Asiedu and Freeman (2009), Wang and You (2012), Wang (2012) and Jiang and Nie (2014). None of the aforementioned studies have analyzed the impacts of corruption on specific investments, like expenditures with R&D. This study contributes to the understanding that corruption perception has different results, depending on the firms' proximity to the frontier.

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