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Determinants of Poverty and Pollution: An Application of a Model of Simultaneous Equations Units in Brazil

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ABSTRACT

Background: This article offers empirical evidence regarding one of the oldest controversies in the economics literature: interfaces between income level and the environment. In spite of the significant debate about possible causal relations among income, pollution and environmental degradation, it has been dominated by oversimplifications of the complex realities involved. They allege, at one extreme, that accelerated population growth is the cause of poverty which is seen as cause of environmental degradation. At the other extreme, the concentration of wealth in the hands of a small percentage of the population is alleged to be the cause of an immense demand of natural resources. Such simplifications have survived for many years because of the scarcity of empirical work testing those hypotheses. **Objective:** The present empirical research was designed to test the relationship among income levels, poverty, inequality and environmental degradation. Multiple linear regression analysis models were used to handle the data gathered from secondary Brazilian sources. **Results:** In spite of most of the robust results obtained, there is persistent evidence of a considerable conceptual hiatus to be overcome if any robust understanding is to be achieved regarding the correlations that exist among income level, income distribution and the use of natural capital by society. **Conclusion:** Poverty may be both a cause and a consequence of high level of environmental degradation just as income distribution inequality may lead to the coexistence of both degradation and conservation of natural capital.

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INTRODUCTION

Generally speaking, developing countries are characterized by high levels of poverty and social inequality. Such countries are faced with the historical challenge of confronting social injustice that has excluded, and still excludes a considerable part of the population from access to a minimum standard of life and well-being. In recent decades, there has been a perception that those problems faced by developing countries are correlated to the degradation of their natural resources and in some cases, to increases in pollution levels (STERN, 1998).

That proposition has motivated a quest for a greater understanding of the interfaces among poverty, pollution and environmental degradation. It should be pointed out that economic analysis occupies itself primarily with addressing the problem of how best to allocate increasingly scarce resources and with their most efficient alternative use, in an effort to maximize social well-being. In developing countries, the economic well-being of many families depends directly on the quantity and the quality of natural resources and the environment (CHIMELI, 2007). For 25 years the relation between income levels and concentration and the use of natural resources has been subordinated to the concept of pollution control. The outreach of that concept has led some analysts, as Cole (2004) in particular, to the simplistic belief that achieving pollution control will also lead to reductions in poverty and social inequality levels.

Against that background, this article aims to investigate, in all 26 Brazilian states and the Federal District, the effects of the relation between income level and industrial pollution on the poor population. To do so, a system of simultaneous equations was estimated relating poverty determinant factors to an industrial pollution

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factor. The methodology was based on the one proposed by Griliches (1977) who first perceived the need to elaborate a system of simultaneous equations that would make it possible to estimate an indeterminate endogenous variable.

In that context, over the last few years there has been a significant interest in the relation between poverty and environmental pollution. In the academic literature various studies have focused on the possible relation of income levels to people's increasing exposure to pollutants being discharged into the atmosphere (PERSSON and TABELLINI, 1994; CARD, 2001; DALY, 2002; COLE, 2004; PERRY, 2006; MURAD, HASHIM and MUSTAPHA, 2010).

Just as an example, it is worth mentioning a study conducted by Salama (2006) that highlighted the importance of the question of environmental sustainability for a country's development and warned about the lack of information on polluting emissions and their consequences for human health

This article is organized as follows: section 2 sets out an analysis of how income and industrial pollution affect poverty levels in the 26 Brazilian states and the Federal District. Section 3 presents the research methods and procedures used; the strategy was to elaborate an analysis based on the use of simultaneous equations to estimate a poverty and pollution system (model) and applying the Generalized Method of Moments to panel data. In section 4 there is the discussion of the results which reveal that all the variables considered in the analysis are in compliance with economic theory and also the existence of a positive significant effect on poverty associated to the states' participation in the Brazilian GDP whereby growth in State GDP is associated to increased industrial pollution levels but also to a lower unemployment rate. Section 5 sets out the final remarks.

A Reminder of the Possible Relationship between Income and Pollution:

The quest for economic development presupposes that there will be economic growth and improvement in individuals' quality of life (SWAN, 1956). Apart from changes in the composition of the gross product and in the allocation of resources along different sectors of the economy, a society's economic development ought to achieve reductions in poverty, unemployment and social inequality, as well as improvement in health, nutrition and housing standards. In the last five decades yet another objective has been associated to a society's economic development, namely, a reduction in the deterioration of its natural capital (TAROZZI and DEATON, 2009).

Thus natural resources represent the stock of potential wealth on which humanity depends to generate its production and income and to raise its level of well-being. Accordingly, economists have stressed the importance of an efficient allocation of natural resources to maximize the population's social well-being as the basis for economic, social and environmental relations. However, that natural capital is becoming increasingly scarce due to population growth, and the accelerated rhythm of wealth generation and accumulation. In their efforts to achieve economic development, human societies are expanding primary production processes and diffusing the process of industrialization (SHAFIK and BANDYOPADHYAY, 1992; KUBRUSLY, 2011).

The use of natural resources to increase economic growth may have negative effects, or externalities, in the form of increase in pollution (DALY, 2002). Those negative externalities are not captured or reflected by the price system, given the technical difficulties that exist to determine exclusive or rival rights to resource use. There is therefore no possibility of establishing exchange relations among those rights that would ensure the optimum use of natural resources. In such cases, the economic value being practiced in the market usually underestimates the cost of opportunity and thus natural resources are overused causing inefficiency and environmental degradation.

While internalizing environmental externalities does increase the efficiency, the gains are perceived differently by the economic agents and they are also dispersed over time so that they affect the intra and inter-temporal income distribution. Hence, economic theory proposes that correcting that market failure should involve defining property rights in such a way that exchanging them via the market establishes a balanced price that effectively represents their social costs (BRUYN, 2000; TEIXEIRA and PEREIRA, 2011).

In his study of pollution, environmental degradation and urban poverty in Brazil, Mueller (1993) argued that most of the problems related to urban poverty and environmental degradation can be can be explained as being the result of unequal economic development.

Degradation may be highly concentrated in the consumption patterns of the high income groups, who have high consumption levels of durable goods, electricity and fresh water, as well as high levels of waste and sewage generation and accumulation. On the other hand, Datt and Ravallion (1992) found inadequate sanitation, overloading and congestion of the sanitation system, degradation of the land surrounding sewage treatment installations and the presence of diseases associated to the inadequate basic sanitation services, especially among people in low income brackets.

Lower income levels may also lead to more pollutant consumer patterns inducing more environmental degradation (MURAD, HASHIM and MUSTAPHA, 2010). When the rate of increase of environmental degradation surpasses the income growth rate, total degradation may increase, accompanying increased consumption levels. Even though, in the case of most of the environmental problems, the technological process affects the intensity of degradation of all social classes indiscriminately, thereby reducing the possibility of imposing a threshold income level, the standard and quantity of consumption in each income bracket group are most certainly varying and directly affecting their environmental impact (ALESINA and RODRIK, 2004).

Nevertheless, income constraints drastically reduce poor people's capacity to do any defensive spending against the negative effects of degradation such as paying for medical care or improving their housing conditions. In other words, the poor probably have to meet a proportion of the environmental costs that is greater than the proportion of the overall population they represent, that is to say they may be consuming the degradation of the rich. Thus economic growth and increasing industrialization in the developing economies have led to an intensification of polluting activities (MOLINA and RAO,2010).

Against that background it must be stressed that such a complex situation cannot be oversimplified. There are other factors in it which must be considered in any attempt to gain an understanding of the interfaces between poverty and environmental degradation. For example, the absence of people's empowerment to participate in political and decision making processes that affect their well-being is increasingly identified as one of the cause of the poorer segments of society living on increasingly degraded environments (BESLEY, BURGESS and VOLART, 2005).

When attention is focused on the quality of the environment, however, the question of its relation to growth is not a consensus. Some researchers like Georgescu-Roegen (1971), Bérgolo *et al*. (2010) and Cechin and Veiga (2010) initially proposed the hypothesis that the higher a country's income level was, the greater would be the extent of environmental degradation through either more pollution or more intensive use of natural resourses. On the other hand, authors like Beckerman (1993), Lopez and Serven (2004), as well as the study from the World Commission on Environment and Development Report (WORLD BANK, 1992), argue that countries with higher income levels tend to reduce environmental degradation as a result of the use of less pollutant technology and the society`s effort to preserve the environment and, therefore, firmly assert that the best way for a country to improve the quality of its environment, in the long run, is for it become wealthier.

Not all researchers agree that there is a direct link among poverty, pollution and environmental degradation. For example Murad, Hashim and Mustapha (2010) state that poverty plays an uncertain or minor role in regard to pollution and environmental degradation. That is because the relation between poverty and the environment is measured by institutional, socio-economic and cultural factors, whereas environmental degradation, in areas of endemic poverty, is brought about by the effects of poor management of macro-economic and institutional policies. To those authors, an improved management of those factors would lead such poor communities to value the environment. In the same way, Wei (2011) asserts that institutional measures must be taken to permit poor communities to improve their resistance in the face of economic shocks and growing environmental risks.

In the light of all the discussions it is not clear whether there is a negative or positive relation between national income growth and the quality of the environment. If it is plausible that environmental quality deteriorates with each product unit produced, it is equally plausible that there should be a decline in the environmental deterioration rate when a certain higher income threshold is attained (BHATTACHARYA and LUECK, 2009).

Fonseca and Ribeiro (2005) and Texeira and Bertella (2010) state that around the year 1970 there was a generalized belief, that a nation's economic growth was largely responsible for environmental problems. According to Deacon and Norman (2004), beginning in the 1990s, economists started to consider the opposite view, that technological innovation, improved education, economic progress and the improvement of institutions resulting from economic growth would in fact induce less environmental degradation. An example of this changing view is Jorgenson and Wilcoxen (2007), who believe that a policy ensuring economic growth lead to environmental protection. Nonetheless, that idea is contested by the works of researchers like Margulis (1992) and Clark (1996), who feel that economic growth performs indiscriminately in relation to protecting the environment.

In that context, the production process normality generates some negative externalities regardless of how much clean production technology is introduced. Reaction against those negative externalities associated to production (and consumption) tends to be positively related to income levels (AFONSO *et al*., 2011). In the same vein, Aghion, Caroli and Peñalosa (1999) stress that higher income levels give rise to environmentally cleaner production and consumption patterns, thereby introducing a technological trajectory of less intense degradation and that whenever the rate of reduction of that intensity becomes greater than the annual income growth rate, then total environmental degradation goes down too, in spite of increased production and consumption levels.

Nevertheless, the effects of pollution are not neutral in terms of the social groups it affects. Gürlük (2009) shows how economic costs associated to urban pollution tend to be greater among the poorer strata of the population. Given that the poor have fewer means of meeting the expense of defensive spending against pollution, they tend to suffer more from its effects. That inequality in the distribution of environmental pollution among the different income level groups also occurs in greater spatial spheres.

It is evident that poorer countries find it more difficult to adopt clean technology due to the high costs involved. That same difficulty applies to the management of post-consumption consequences (COLEA and FREDRIKSSON, 2009). The same argument can be applied to different geographic spaces in Brazil. The fact is, however, that there is a generalized absence of statistics on pollutant emissions and their impacts on social segments in Brazil. That absence makes it difficult to conduct a systematic analysis of the Brazilian industrial sector's environmental performance and its effects on the population's health in the various regions of Brazil. It is known, however, that according to the Brazilian Geography and Statistics Institute (InstitutoBrasileiro de Geografia e Estatística – IBGE) (IBGE, 2010), large urban areas put great pressure on natural resources due to the absence of basic sanitation, the low quality of housing, the difficulty of accessing public health services and other problems stemming from the low income levels of our population (MOLINA and RAO, 2010).

One of the facts that has aggravated the consequences of environmental impacts for the populations of Brazilian cities has been the extremely rapid transition, in less than a century, from being a predominantly rural society to being an essentially urban one (Mueller, 1993). In 70 years the total population increased almost fivefold while at the same time the rural population went down both in absolute numbers and as a percentage of the total in comparison with the baseline reality of 1940. According to the preliminary data of the 2010 demographic census, 84% of Brazilians, that is 160.1 million people live in the urban milieu. In the year 2000, 81% of Brazilians lived in urban areas.

Again according to the 2010 demographic census, income inequality is still very high in the Brazilian cities in spite of the trend to reduction observed over the last 10 years. Even though the average per capita income for households in 2012 was 668 Brazilian reals, in that same year 25% of the population received 188 reals or less and half of all Brazilians received 483; an amount lower than the official minimum salary at the time (622 reals).

It is important to reiterate that there is a generalized absence of statistics on pollutant emissions, making it difficult to conduct a systematic analysis of the Brazilian industrial sector's environmental performance and its effects on the population's health in the various regions of Brazil. Nevertheless it is possible to measure the expansion of those industrial sectors with the greatest emissions potential and that has been done by the indicators constructed by the IBGE's Department of Industry. The building of those indicators is based aggregating the physical industrial production in classifications reflecting the industrial activities' power to pollute (high, medium, low or negligible).

Methods and Procedures:

The simultaneous equations method is used in this article to estimate a model that relates poverty determinant factors to an industrial pollution factor as shown in Equations 1 and 2. The estimators for the equations' coefficients were calculated using the methods of Ordinary Least Squares (OLS) and Fixed Effects Least Squares (OLS-FE), and the Generalized Method of Moments (GMM).

The OLS method is used to estimate a classic linear regression model. In general terms and with due observation of the Gauss-Markov theorem, the OLS parameters are the best unbiased linear estimators, that is to say, the expected value for each estimator is equal to the parameter for the model that is to be estimated, so that the OLS may be the most efficient. The OLS-Fixed Effects method is used as a way to minimize the effects of any variability present in the OLS model. Thus the OLS-FE method is the one that offers the most plausible estimators (HAYASHI, 2000).

GMM offers an efficient alternative for handling and solving the problems of endogeneity because it performs well in the presence of homoscedasticity and leads to the orthogonality of the results with out of phase models. Furthermore, the estimated coefficients are similar to those of the fixed effects model. In the case of GMM estimations it is possible to include variables that are strictly endogenous, that is to say, not correlated to error in any period.

On the basis of those reflections, the following two multiple linear regression models were estimated.

$$\mathbf{pl_{it} = \alpha_0 + \alpha_1 stategnd_{it} + \sum \alpha_2 xpl_{it} + \varepsilon_i + \lambda_t + \upsilon_{it}} \quad (1)$$

$$\mathbf{pv_{it} = \beta_0 + \beta_1 stategnd_{it} + \beta_2 pl_{it} + \sum \beta_3 xpv_{it} + \mu_i + \gamma_t + \xi_{it}} \quad (2)$$

Equation 1 represents the expansion of those industries with the greatest emissions potential used as a proxy for pollution levels(pl). The variable(xpl_{it}) represents the exogenous factors that determine pollution: urbanization rate (urban) and the unemployment rate (un). Equation 2 represent the level of poverty (pv) of the population as a function of pl. The variable (xpv_{it})represents the factors determining poverty: Gini coefficient (Gini), infant mortality rate (mr) and education (edu). The variable $stategnd_{it}$ represents the participation of each state (i) in the national gross domestic product (GND)

Parameters β and α represent the consistent estimators. The terms ε and μ represent the matrixes of the dummy variable for the states and Federal District (the individual effects). Parameters λandγ stand for the dummy temporal variables. The stochastic terms υand ξ mirror the variables that have been omitted or incorrectly calculated (HAYASHI, 2000).

The aim of the estimations made using OLS and OLS-FE was to identify whether the coefficients are predominantly significant. According to economic theory, it can be expected that any increase in the state industrial GDP's participation in the national GDP (stategnd) will lead to an increase in pollution levels. In Equation 1, it is presumed that any increase in the urbanization rate (urban) will give rise to an increase in pollution levels and that an increase in the unemployment rate (un), can be expected to be associated to a reduction of the state GDP participation and to a reduction in pollution levels. An investigation will also made to verify whether the GMM regression revealed any significant degree of relation between the unemployment rate (un), the state GDP's participation in the national GDP (stategdp),and the urbanization rate (urban) to the pollution of the Brazilian states, that is, whether there is any positive or negative causality among the explanatory variables defined by the model. An analysis will be made as to whether the variable urbanization rate (urban) is, in turn, statistically significant when the other control variables are statistically relevant.

In Equation 2, it is expected that any increase in the state industrial GDP's participation in the national GDP (stategdp) will lead to a reduction in the poverty level (pv), that a rise in the urbanization rate (urban) lowers the GDP participation and the pollution levels (pl), that years of schooling (edu) have a negative relation to the level of poverty (pv) and that fetal mortality (mr) have a positive relation with population poverty (pv). A verification of the GMM regression was made to check for any evidence of the importance of the unemployment rate (un), the state industrial GDP's participation in the National GDP (stategdp),the urbanization rate(urban), years of schooling (edu),and number of fetal deaths (mr) for the poverty levels in the respective Brazilian states and Federal District, that is, whether there is any positive or negative causality among the explanatory variables defined by the model. An analysis will be made as to whether the variable urbanization rate (urban) is, in turn, statistically significant when the other control variables are statistically relevant.

Table 1 displays the variables of Equations 1 and 2, the expected signs associated to the coefficients according to economic theory, estimated using OLS, OLS-FE, and GMM in addition to the descriptions of the variables and the data sources.

Table 1: Variables in the estimation of Equations 1 and 2 by OLS, OLS-FE and GMM and the expected signs of the coefficients.

Estimated Equation Parameters						
	Var	OLS	OLS (EF)	GMM	Descripton	Source
Equation 1	pl				Dependent variable - Expansion of industrial sectors with greatestemissions potential.	Ipeadata - Pnad.
	un	-	-	-	Unemployment rate.	Ipeadata.
	urban	+	+	+	Urbanization rate.	Pnad.
	stategdp	+	+	+	Participation of state GDP in National GDP.	Ipeadata.
	yr1990		-			Pnad.
	yr1991		-			Pnad.
	yr1992		-			Pnad.
	yr1993		-			Pnad.
	yr1994		-			Pnad.
	yr1995		-			Pnad.
	yr1996		-			Pnad.
	yr1997		-			Pnad.
	yr1998		-			Pnad.
	yr1999		-			Pnad.
	yr2000		-			Pnad.
	Cons	+	+	-		
Equação 2	pv				Dependent variable - Poverty	IpeadataPnad.
	pl	-	-	-	Expansion of industrial sectors with greatest emissions potential.	IpeadataPnad.
	un	+	+	+	Unemployment rate.	Ipeadata.
	urban				Urbanization rate.	
	stategdp	-	-	-	Participation of state GDP in National GDP.	Ipeadata.
	edu	-	-	-	Years of Schooling.	Ipeadata.
	mr	+	+	+	Number of fetal deaths.	Pnad.
	yr1998		-			Pnad.
	yr1999		+			Pnad.
	yr2000		-			Pnad.
	yr2001		+			Pnad.
	yr2002		+			Pnad.
	yr2003		+			Pnad.
	yr2004		+			Pnad.
	yr2005		+			Pnad.
	yr2006		+			Pnad.
	cons	+	+	+		

For each dependent variable appearing in Table 1 there is an expectation according to economic theory set out in Table 2.

Table 2: Expectations or expected patterns for the dependent variables.

Dependent Variables	Economic Expectation
pl	It is intended to confirm whether there is a positive relation between pollution and income in regard to the states and whether environmental conservation is directly related to the participation of the state's industrial GDP in the national GDP (stategdp).
pv	It is intended to confirm whether there is a negative relation between poverty and pollution in the states and whether environmental conservation is directly related to the participation of the state's industrial GDP in the national GDP (stategdp).

The validity of the results obtained using GMM is verified subjecting them to the Hansen test and Arellano and Bond's (1991) serial correlation test. The serial correlation test was used to test the null hypothesis that no serial correlation exists while the Hansen technique tests the hypothesis that the instrumental variables are correlated with the error term and correctly excluded from the estimated equation. The idea is to verify whether the statistics F shows itself to be globally significant and to what level of significance for all the regressions carried out and also whether the value of R^2 to be adjusted by the fixed effect model is capable of detecting whether the explanatory variables can indeed evaluate the total poverty. The models were estimated using the 10.0 version of the statistics software Stata.

RESULTS AND DISCUSSIONS

The estimates of the coefficients of the proposed models (Equations 1 and 2) proved to be consistent with economic theory expectations. The result of the F test applied to the estimates associated to Equation 1 generated by OLS (143.46) and the OLS-FE (65.42) showed that the model is globally significant.

In the estimations obtained using OLS-FE it can be seen that the coefficients are predominantly significant (t statistics) to significance levels of 5%, 10% and 15%. (with the exception of dummy temporal variable for the year 2000, statistically significant to the level of 10%). Furthermore, it can also be seen that the explanatory variable participation of the state industrial GDP in the National GDP (stategdp) had a high statistical significance (t=15.38). The adjusted R^2 value of 0.70 shows that the equation's set of determinant factors (unemployment rate – des; urbanization rate – urban; state industrial GDP's participation in the national GDP (stategdp) explains the Brazilian state's pollution to the extent of 70% (Table 3). It should be borne in mind that the temporal effects have significant negative impacts throughout the temporal series (except in the year 1993 when the tendency changes but the trajectory is taken up once again in the following years) and there is an overall reduction of poverty somewhere between 1.64% and 0.43%.

The validity of the results obtained using GMM is verified subjecting them to Hansen's test and Arellano and Bond's (1991) serial correlation test. Hansen's test indicates the probability of the instruments being 16.5% (21.36) orthogonal and the Arellano-Bond correlation tests indicates a 79.5% (z = 0.26) probability of there being no second order correlation (Table 1).

Table 3: Estimated parameters for Equation 1 (pollution) using OLS, OLS-FE and GMM method and the t Test (in brackets).

	(1-OLS)	(2-OLS-FE)	(3-SYSTEM GMM)
un	0.0734***	-0.0437**	0.0856*
	(3.70)	(-1.93)	(-1.89)
urban	0.0124*	0.0174***	0.123**
	(1.84)	(2.86)	(2.47)
stategdp	0.137***	0.148***	0.0953*
	(12.86)	(15.38)	(1.82)
yr1990		-1.637***	
		(-5.68)	
yr1991		-1.582***	
		(-5.86)	
yr1992		-1.389***	
		(-5.58)	
yr1993		-1.504***	
		(-6.17)	
yr1994		-1.502***	
		(-6.18)	
yr1995		-1.440***	
		(-5.92)	
yr1996		-1.330***	
		(-5.52)	
yr1997		-1.322***	
		(-5.52	
yr1998		-0.844***	
		(-3.58)	
yr1999		-0.609**	

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		(-2.59)	
yr2000		-0.433*	
		(-1.84)	
_cons	0.461	2.194***	-6.602*
	(0.95)	(4.62)	(-2.22)

$R^2$0.63 R^2aj 0.70 F= 143.36 65.42 Arellano-Bond test for AR(2) z = 0.26 (0.795)
t statistics in parentheses. * p<0.10 ** p<0.05,*** p<0.01

A Equation 1 shows the existence of a positive relation between pollution and the relative incomes of the states. Environmental conservation is directly related to the states' relative participations in the national GDP (stategdp). The GMM regression reveals the importance of the unemployment rate (un), the states' participation in the national GDP(stategdp) and the urbanization rate(urban) for the level of pollution generated by the Brazilian states. Causality between the level of pollution and the unemployment rate is negative. Between pollution level and all the others it is positive.

The variable urbanization rate, in turn, is statistically significant to a level of 5% while the other variables are statistically relevant to a level of significance of 10%. The research made it possible to verify that the urbanization rate had an impact to the level of 12.3% in relation to pollution. An annual increase of 1% in the urbanization rate leads to an annual increase in pollution of 0.12%. Urbanization and industrialization can alter the characteristics of the global climate which in turn can have direct effects on air pollution. As an example, the formation of the so-called "Urban Heat Islands" is a phenomenon that occurs in urban areas and brought about by pollution which causes temperatures to rise and air humidity to fall (SANTAMOURIS, 2001, COLEA and FREDRIKSSON, 2009).

In the case of Equation 2, the statistical value F generated by the OLS method (344.83) and by the OLS-EF method (215) showed that the model is globally significant to a significance level of 1%. The value obtained for the adjusted R^2 of the model estimated by the fixed effect method showed that the set of explanatory variables explains 0.81% of the total variation in the level of poverty.

The GMM tools were shown to be consistent by the Arellan and Bond (1991) serial correlation test with a value for p = 0.271 (z=1.10) and by Hansen's test with p-val = 0.115 (24.16) at a significance level of 5% (Table 4). Those values guarantee that the term of error is not serially correlated and that the moment conditions are correctly specified. The Hansen's test shows there is a 24.16% probability of orthogonality for the GMM tools and the Arellan-Bond test shows an 11.5% probability of second order correlation's not occurring.

The results show that there is an obvious correlation between poverty levels and income levels because the coefficients are statistically significant to the level of 5% for all three estimation methods used (OLS, OLS-FE and GMM). Exceptions appear among the dummies for temporal effects for the years 1998 and 1999 for the Fixed Effect models. The explanatory variables pollution (pl), states' participation in the national GDP (stategdp) and schooling years (edu) are negative, while the coefficients for unemployment rate (un) and infant mortality rate (mr) are positive. The signs obtained for the explanatory variables estimated by the three methods are in accordance with the hypotheses formulated and with the majority of the analyses undertaken and described in the specialized literature.

Table 4: Equation 2 parameters estimated by the OLS, OLS-FE and GMM methods and t Test (in brackets).

	(1-OLS)	(2-OLS-FE)	(3-SYSTEM GMM)
pl	-0.0149***	-0.0210***	-0.0513***
	(-5.24)	(-6.71)	(-2.43)
stategdp	-0.00662***	-0.00589***	-0.0484***
	(-4.92)	(-4.57)	(-2.44)
edu	-0.640***	-0.669***	-0.466***
	(-30.19)	(-32.19)	(-4.51)
un	0.0153***	0.0143***	0.0173***
	(11.03)	(9.40)	(3.13)
mr	0.0000235***	0.0000274***	0226***
	(4.24)	(5.06)	(2.75)
yr1998		-0.0106	
		(-0.66)	
yr1999		0.00933	
		(0.56)	
yr2000		-0.0433**	
		(-2.58)	
yr2001		0.0336**	
		(2.01)	
yr2002		0.0311**	
		(1.88)	
yr2003		0.0695***	
		(4.11)	
yr2004		0.0710***	

		(4.22)	
yr2005		0.0479**	
		(2.75)	
yr2006		0.0459**	
		(2.68)	
_cons	1.401***	1.460***	1.122***
	(46.45)	(48.36)	(7.13)

R^2 0.79 R^2ajust 0.81 F= 344.83 215.00 Arellano-Bond test for AR(2) z = 1.10 (0.271)
Hansen test of over-identifying restrictions chi2(17)_ (24.16) 0.115 t statistics in parentheses. * p<0.10 ** p<0.05,*** p<0.01

Years of Schooling is the explanatory variable with the greatest impact on poverty reduction indicated by the fact that its coefficient values are higher and more significant than all the others for the three estimation methods. The negative relation of this variable to poverty [(β = – 0.640 (OLS); β = – 0.669 (OLS-FE); β = – 0.466 (GMM**)]** means that the higher the level of education, the lower the poverty index. The poverty index goes down consistently as the number of schooling years increases. As an example, based on GMM values it can be seen each additional year of schooling, on average, reduces the poverty index by 0.47%.

Econometrics theory suggests that the economic interactions involved in the relations between pollution levels and poverty levels are complex and so the most suitable means of studying that interdependence was to make use of a set of simultaneous equations, as represented by equation (1) and equation (2), to identify any causality among them. Such models are known as "simultaneous equations systems" because the exogenous variables are determined simultaneously and the equations that are part of the system are estimated simultaneously (GRILICHES, 1977).

According to economic theory, the explanatory variable pollution (polluting industries) has a negative relation with the poverty index. The greater the amount of pollution generated by industrial production the more the poverty index will go down. The negative sign of the estimated coefficient (– 0.0513 by the GMM) tells us that an increase of 1% in the production of those polluting industries will tend to reduce the poverty index by 5.1% a year. That is indicative of poor people's tolerance in regard to living and working in places with the highest levels of pollution and environmental degradation. Here we have two sides of the same coin: the company that pollutes also generates employment and income.

In none of the three regressions did the state GDP's participation in the national GDP show itself to be significant. In the equation estimated by the OLS method it can be seen that an increase of 1% in the states' participation in the national GDP leads to a 4.8% reduction in the poverty index mirroring the poor population's improved living conditions.

Parallel to to that, a 1% increase in the unemployment rate implies a possible drop in the GDP value which in turn would be accompanied by a reduction of pollution by 8.56%. The higher the unemployment rate, the lower the pollution rate. More specifically, the unemployment leads to a reduction of pollution to the order of 0.09% a year. The negative relation between the unemployment figures and pollution is therefore directly related to industrial production. The results reveal a strong negative association between the unemployment rate (5.56%) and the participation of the state's industrial GDP in the National GDP (9.53%) thus corroborating the postulate of economic theory that positive variations in economic activity provoke negative variations in the unemployment rate.

Generally speaking, the results indicate that there is a significant positive effect of the states' industrial GDP's participation in the national GDP on the pollution index. In other words, whenever the state industrial GDP participation increases, the there is an increase in the pollution indicators and consequently that may lead to a reduction in the unemployment rate (improved income conditions).

Conclusions:

The links between income (level and distribution) and natural capital (use, degradation, pollution and conservation) has challenged economists for decades. Even so the thinking on those connections has presented chronic differences and has generated extremist stances that cannot be reconciled. This paper has verified that one of the reasons for those differences and incompatibilities stems from the relative scarcity of empirical verifications of the theoretical variations that have been put forward by environmental economists. The interfaces of income (level and distribution) and natural capital (use, degradation and conservation) have been relatively neglected topics in the empirical studies of economists interested in environmental problems. This article has sought to close that gap by means of an empirical test of the arguments usually put forward in the specialized literature.

The study reported here investigates the relations between poverty (low income level) and industrial pollution in the Brazilian states and Federal District. This empirical verification sought to identify possible causality relations by using a set of simultaneous equations whereby exogenous factors are determined simultaneously and the equations that are part of the system are estimated simultaneously. The results suggest that there is a negative relation between the levels of industrial pollution and poverty rates among the Brazilian states and Federal District: the greater the amount of pollution stemming from industrial production, the more the poverty level will go down. That is indicative of poor people's tolerance in regard to living and working in places with the high levels of pollution and environmental degradation. Here we have two sides of the same coin: the company that pollutes also generates employment and income.

The models proposed by Equations 1 and 2 obtained using the simultaneous equations method confirm the correlation that existed between income level, pollution levels and poverty levels in the Brazilian states and Federal District for the period 1990 to 2008. Against that background, a review of the theoretical elements present in the discussions on income level, pollution and poverty clearly reveal the complexity involved in trying to fully apply them to the conflicts that are inherent to the inter-relations between the social sphere and the environmental sphere. The analysis of the data on the Brazilian states shows that the variables associated to income may be positively related to some of the environmental variables.

In light of the proposed objective of examining possible correlations among variables associated to the concept of pollution and poverty - social indicators such as schooling years, urbanization rate and others mentioned above – it was found that they were, in general, correlated to economic and environmental aspects. That underscores the need to create mechanisms that will foster public policies that do not set priority on the states' economic growth alone, but above all, on improving the social indicators, especially in regard to improved income distribution patterns, pollution control and access to education, all of which are of fundamental importance to ensure that the environment is respected and that future generations will not have to pay the price.

There are various comments that can be made on the basis of the test results set out in this article. One is that economists in general and environmental economists in particular have neglected crucial aspects of the link between income (level and distribution), the environment and pollution processes associated to economic growth. There are various reasons for that negligence. Two of them can be derived from our research: one is conceptual and the other stems from the limitations of official statistics.

The conceptual reason suggests that, in the course of the last few decades, there has been little evolution in terms of analyzing the links between income level, inequalities in income distribution and the use of natural capital. It was found that many analysts view the environment as a kind of "luxury goods"; a view that was popularized by the World Bank's 1992 World Development Report which suggested that there was an empirical relationship between per capita GDP and concentrations of industrial pollutants. The presumption was that it will always be possible to recuperate the stock in the future because natural capital is capable of recuperating itself. According to Fare *et al*. (2004), biodiversity studies have shown that to be a false assumption: the existence of ecological thresholds means that damage to ecosystems may be irreversible.

This study sets out numerous observations regarding empirical research involving income, pollution and the use of natural resources (capital). Its outstanding feature is that it shows that the creation of wealth may collide with environmental conservation and may co-exist with locations whose poverty is a current realty. There can be no doubt that the enrichment of our conceptual framework in regard to the theme of this article is an essential component of any agenda for future research. Thus, the practical reason explaining why there is poverty, namely, inequality, environmental degradation and the influence both of them have on natural capital is still not on the economists' research agenda and that is related to the quantitative and qualitative limitations of the empirical databases for those variables, especially in a country's less developed regions. While there is admittedly a large number of sources of information on poverty and pollution, the same cannot be said of the information available on income distribution or on the impacts that different social groups' activities have on natural capital. As long as that scarcity of data sources continues to be the rule in the reality of regions and/or countries, certain hypotheses that have never actually been tested will continue to be held to be true.

Finally, it must be stressed that the main limitation to this work has been not making a comparison of the results obtained with the classic approach of economics. It is worth stating that the empirical verification sought to illuminate possible causal relations by means of a set of simultaneous equations whereby the exogenous variables are determined simultaneously and the equations that are part of the system are estimated simultaneously. The results suggest that there is a negative relation between the levels of industrial pollution and poverty rates among the Brazilian states and Federal District: the greater the amount of pollution stemming from industrial production, the more the poverty level will go down. That is indicative of poor people's tolerance in regard to living and working in places with the high levels of pollution and environmental degradation. Here we have two sides of the same coin: the company that pollutes also generates employment and income. In that light it is suggested that future studies should make a comparison between the two approaches.

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