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The Growth-Sustainability Dilemma in BRIC

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Abstract

Brazil, Russia, India and China (BRIC) are important countries that in the last two decades have become strong, both economic and politically. Due to the importance of these countries as emerging economies, and taking into account the current need for countries adhering to environmental standards, a relevant issue to investigate is if increasing levels of Gross Domestic Production (GDP) are tied with decreasing levels of environmental performance. This paper aims to analyze this growth-sustainability dilemma, focusing on BRIC's economic and socio-environmental performance from 1990 to 2011. Theories on production-cum-environment and the sustainable development concept are presented to support the analysis and guide the empirical study. Statistical correlation analysis was the method used to measure the strength of the relationship between the trajectories of GDP and the behavior of the economic, social and environmental indicators selected. Results showed that GDP growth has occurred with advances in sustainable development, mainly in the economic and social pillars, but the dilemma showed up: GDP growth has been stronger in less sustainable countries, with China scoring as the worse in environmental performance and the leader in GDP growth. We conclude the paper with a concern on how feasible sustainability is for the BRIC countries.

Keywords: *BRIC, GDP Performance, Growth, Sustainability, Sustainable Development.*

Introduction

Economic growth and development has been a subject of great importance since the first contributions of leading economists, such as Adam Smith's "The Wealth of Nations", published in England in 1776. Throughout the years many other important authors have developed works focusing on growth and development, but only in the forties and fifties of the 20th century more elaborated papers on this theme appeared, e.g., the contributions of Domar [1] and Solow [2,3] on growth and Rosenstein-Rodan [4] and Nurkse [5,6] on development. Domar [1], for instance, emphasized the role of industrial investments in physical capital to prompt production growth, while Solow [2,3] focused on both the role of technological advances to induce production growth and the way total factor productivity is measured to assure that production growth is obtained via technological progress.

On the development side, Rosenstein-Rodan [4] emphasized the role of complementarity in industrialization processes, and the relevant contributions by Nurkse [5, 6] pinpointed to the 'vicious-virtuous' circles upon which the formation of capital in underdeveloped areas was subjected.

Despite the importance of these seminal contributions on economic growth and development in the forties and fifties, the main works of the modern theories of endogenous growth-development were published during the 1980s and 1990s, such as Romer [7] and Lucas [8] who highlighted the relevance of human capital, education and knowledge to prompt development, and Grossman and Helpman [9, 10] who brought and treated trade as an important source of endogenous production growth and development. In this modern perspective it is no more appropriate to separate growth and development, as in the 1940s and 1950s, since many of the social variables linked to development in the previous period had to be incorporated into the new developments of the modern production growth theories.

A huge change on the prospects of traditional and modern economic growth-development theories has occurred since the late eighties, under the influence of the Brundtl and Commission [11], mapping a new direction to target the environment as a key variable to be considered in any attempt of a country to develop. Accordingly, current theories of economic growth-development have embodied environmental variables into their specifications in a way to analyze the implications to rapid production growth when the environment

is taken into account.

Important recent contributions, e.g., Geldrop and Withagen [12], Palmada [13], Islan [14], Charles [15], Comolli [16], Bretschger and Smulders [17], Auty [18], and Voinov and Farley [19], have used analytical frames jointly treating output production and environmental variables under a single theoretical approach. Daly [20] seminal contribution on ecological economics and sustainable development is a conceptual work elaborated with no relation to growth-development models, but with important implications to sustainable development strategies. Najam, Runnalls, and Halle [21] offered important propositions for environmental safety under the globalized production processes in course worldwide.

It is obvious that the upgrade of growth-development theories to include the environment has had important implications to academic and political issues, as well as to development policy design and implementation. Due to this, strategic sustainable development policy supported by the theoretical contributions presented in next section will be discussed, considering the BRIC countries as important players in a changing world where production adjustments are being implemented to cope with strategies that prioritize sustainability. New emerging economies have to be aware of not repeating the mistakes of some today's advanced countries that damaged the environment in their earlier phases of rapid production growth. China is a concern on this matter today, and its outstanding GDP performance has to be checked under the premises of sustainable development.

Globalization is also an important event in our contemporary era of economic openness. It is a known fact that FDI flows have intensified since the beginnings of globalization, and mainly in the last two decades (1990s and 2000s), a period of time where a set of developing countries emerged as potential candidates to become developed. Brazil, Russia, India and China (BRIC) have been experiencing sustained phases of production growth, leading them to a status of emerging economies and important destinations for FDI flows.

Due to the current need for outstanding production performance, mainly when emerging economies are the focus, a dilemma has emerged: how compatible are the targets of rapid production growth and sustainability? We analyze this dilemma considering the BRIC countries performance on a set of economic, social and environmental variables.

In next section the relevant theories on production-cum-environment and the concept of sustainable development are presented to give support to the analysis. A brief discussion on related strategic development policy is conducted to show how important is to bring together economic and socio-environmental variables. We start with two production-cum-environment models and end the section with the concept of sustainable development.

After this, the statistical correlation method is presented and arguments on its appropriateness are elaborated. The empirical evidence is presented. Statistical correlation analysis is applied to investigate the strength of the relationship between GDP growth and the performance behavior of the economic, social and environmental variables selected. In general, the evidence shows reasonable and good performances on economic and social variables (except for Russia), but bad ones on environmental variables. China, closely followed by India, is the worse on environmental standards. The dilemma is evidenced: GDP growth has been stronger in less sustainable countries. China scores as the worse country in environmental performance, and it is a leader in GDP growth. Conclusion ends the paper with the most important findings and a concern about the feasibility of the sustainability perspective for the BRIC countries.

Theories on Production with Environment and Sustainable Development

This section presents a set of growth-cum-environment models trying to bridge production and environment. A brief discussion on strategic sustainable development policy is conducted based on the insights coming from the theories analyzed. This section ends with the Brundtland Commission [11] document, a crucial publication that has pioneered the concept of sustainable development. The growth-sustainability dilemma is considered in order to guide the empirical exercise in other section.

Production-Cum-Environment

Two classes of environmentally-based production growth models are presented: production growth using finite and depletable natural resources; and output growth with pollution as waste generation. The first pioneering production-environmental model comes from Anderson [22], who explored the implications to production growth from explicitly accounting for depletion of a no reproducible natural resource, such as a fossil fuel reserve. Stiglitz [23] used a similar construction to model production growth in the presence of exhaustible natural resources. More recently, Amigues, Favard, Gaudet, and Moreaux

[24] and Palmada [13] formalized optimal allocations of different natural resources, such as air, water and forests, during production phases.

A second class of models was pioneered by Forster [25, 26] who brought an important feature not considered in standard production growth models. He presented an optimal physical capital accumulation model taking into account the possibility of waste generation (pollution). Other recent models of pollution generation under optimal environmentally- based output growth can be cited, as Lyon and Lee [27]; Chakravorty, Moreaux and Tidball [28] and Chakravorty, Magné, and Moreaux [29].

In the two classes of pioneering production-cum-environment models mentioned to above the authors follow the standard procedure of considering a one-sector economy, such as in Bretschger and Smulders [17] analysis of optimal uses of nonrenewable resources, or in Farzin and Akao [30] and Voinov and Farley [19] who included renewable natural capital into an output growth model in an one-sector economy.

The most important feature of the pioneer Anderson's [22] model is that when the nonreproducible stock of natural resources is considered, the result shows a tendency to postpone capital accumulation and spend time on production growth paths where capital is used less intensively than in models of unconstrained natural resource uses. Therefore, the basic prediction coming from this growth model accounting for depletable natural resource uses points to a general slowdown trend of production. This is so because the constraint poses a limiting restriction on the use of depletable resources, which leads to a reduced rate of physical capital accumulation, driving production downwards. It is optimal to slow down the country's capital accumulation (decreasing production) when depletable natural resources are considered.

Recent contributions have shown this same result in different contexts. Comolli [16] investigates the relation between natural and physical capital during specific production growth phases, and Farzin and Akao [30] study optimal exhaustion of a nonrenewable under different production settings.

Following the other pioneering production-cum-environment model, Forster [25] states that "It is naive to think that no wastes are produced and fairly obvious that the free disposal assumption of the neoclassical growth model is not satisfied in the real world". The most relevant prediction coming from this environmentally-sounded production model points out that when pollution is accounted for, the production process tends to a lower physical capital accumulation than when pollution control is not considered, the same prediction coming from the analysis of the depletable natural resource model by Anderson [22].

These predictions show us that theoretically, when we consider production-cum-environment models, the growth-sustainability dilemma is explicit, a relevant aspect to guide the empirical exercise and to consider strategic sustainable development policy.

Production-cum- Environment and Sustainable Development Policy

Having presented the two classes of output growth models accounting for environmental variables, on the one hand, considering exhaustible natural resources, and on the other, pollution as waste generation, we should say that these refinements were important improvements in terms of offering a better theoretical frame to consider strategic economic-environmental policy in practice. Surely, at least in terms of introducing environmental variables, the models discussed above seem to have their relevance for design and implementation of strategic sustainable development policy. Introduction of environmental variables into output growth models, as posed by Auty [18], has been "reinforcing the rationale for the sound management of natural resources and also … providing an index of policy sustainability".

It is true that depletable resources, pollution generation, production and consumption are all interrelated issues, and to be fully complete such models would have to consider all aspects at the same time. To deal with environmental issues in a pertinent way, political and institutional frameworks must play a very important role. These extensions are related to the many facets of the real world complexities linked to sustainability, with important implications to sustainable development policy.

A comprehensive set of contributions related to sustainability taking into account its wide range of complexities is as follows. Musson [31] - sustainability and business attractiveness; Spangenberg [32] - economic sustainability of the economy; Haake and Jolivet [33] and Stagl and O'Hara [34]- adjustments on production, consumption and consumer behavior to attain sustainability; Pfahl [35]- institutional sustainability to operationalize sustainable

development; Hammar [36] - environmental institutions in environmental policy; Costantini and Monni [37] - institutional sustainability and output production; Littig and Griessler [38] - social sustainability to bridge political pragmatism and social theory; Wilkinson and Cary [39] - sustainability as an evolutionary process; Hinterberger, Luks, Stewen and Straaten [40] - sustainability as a co-evolutionary perspective to base environmental policy; and Bolay [41] - international scientific cooperation to attaining sustainable globalization.

All these contributions are very important in their roles to frame sustainable development strategies in a complex reality, mainly when policy making is concerned. We clarify that the real world complexity involving many multifaceted issues related to sustainability is out of the empirical scope of this study. As it will be seen later, we operationalize sustainability through a simple set of environmental indicators related to the third pillar of sustainable development.

Linking the main predictions of the two classes of environmentally-sounded production models with the environmental pillar of sustainable development, we saw that slowing down the pace of output growth is feasible and desirable, for the stock of nonrenewable natural resources cannot be totally depleted and production activity is in its course, albeit at a slower pace. As suggested by Holland [42] and Irwin and Ranganathan [43], it is also possible to rule the rate of depletion of the nonrenewable natural resource in such a way that the rate of regeneration of renewable natural capital is always higher, and thus augmentation of total natural capital could be obtained. This arrangement would at least preserve the constancy of the total stock of natural capital, a pre-requisite to sustainability and an important signal to base sustainable policy in practice. As argued by Rey-Valette, Laloe and Fur [44], an aside issue concerning policy design and implementation is the use of sound sustainable development indicators.

These issues are of crucial importance to the BRIC countries, since sustainability implies a balanced use of renewable and nonrenewable natural resources. Also, pollution generation is a huge problem, mainly in China. Dealing with such issues is a complicated matter. Based on the predictions coming from the production-cum-environment models, how to implement a sustainable development policy targeting a strategy to slowdown production growth to preserve natural resources or reduce pollution? This growth-sustainability dilemma in the BRIC countries, the main focus of the paper, will be empirically investigated latter.

The Concept of Sustainable Development

As stated by Sena [45] "the well known fact that today's economy activities are imposing a heavy burden on the earth's capacity has led to an increasing interest in sustainable development and related issues. It has been emphasized that economic growth depletes the current stock of natural resources and damages the environment and that there are clearly economic limits to rapid growth" (p. 214).

Despite the classical pro-technology optimistic arguments, which poses that technical progress is what is needed to eliminate all constraints on production growth the approaching exhaustion of many natural resources is a reality. Even mining, an economic activity that is alleged to be free of its finite mineral resources exhaustion, i. e., where the classical pro-technology optimistic arguments are supposed to apply, according to Mudd [46], is now facing trouble, since evidence on decreasing ore grades, increasing mine waste rock and deeper and larger mines are easy to find.

Current discussions on those issues and attempts to design sound socioeconomic and environmental policy to improve welfare of populations worldwide have had, as a supporting frame, the pioneer definition of sustainable development coming from the Brundtland Commission [11]: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Holmberg and Samdbrook [47] emphasized that the Brundtland Commission gave geopolitical significance to the sustainable development concept.

Many other definitions have followed, all including economical, social, political, institutional and environmental issues to assure that future generations must have not less than we have today. As taking into account the economic, social and environmental pillars, Environment Canada [48] states that "The integration of environmental sustainability with economic competitiveness and productivity and social equity lies at the core of sustainable development ... It is an approach that seeks to ensure that in meeting our current needs, we do not jeopardize the ability of future generations to meet their needs" (p. 2).

Daly [49] defines sustainable development as "dependable on the maintenance of physical

throughput over generations… Natural capital is to be kept intact. The future will be at least well off as the present in terms of its access to biophysical resources and services supplied by the ecosystem" (p. 1). Gamage and Boyle [50] offer a comprehensive review of the concept of sustainable development, including the important aspects of consumerism, materialism, and psychological and business aspects, while analyzing the concept in terms of its theoretical advances.

As it was seen, sustainable development and sustainability are multifaceted and complex matters. Attaining sustainability requires great efforts from different classes of society and agents of the economy. Emerging economies such as the BRIC countries have an important role to play in the current scenario of rapid production growth under natural capital constraints. Back to the main focus, and remembering the predictions from the production-cum-environment theoretical models – when constrained by limited natural resources production has to slowdown – we ask: is there a growth-sustainability dilemma in the BRIC countries? The empirical evidence in section 3 brings the performances of Brazil, Russia, India and China for the last two decades to answer this question.

Method: Statistical Correlation Analysis

Statistical correlation is a technique used to measure if two variables are related. For example, consider the variables disposable income and consumption of an individual. It is expected that these two variables increase or decrease together, i. e., they are related in the sense that a positive (negative) change in one variable is accompanied by a positive (negative) change in the other variable. In this case, we say that disposable income and individual consumption are positively correlated. If increasing income-consumption is a consequence of increasing production that to be obtained damages the stock of natural capital, then increasing production and decreasing stock of natural capital are said to be negatively correlated. We say production and natural capital are related variables: when production increases natural capital will tend to decrease and vice versa.

According to Choudhury [51], correlation analysis is about relationship between variables and gives us two relevant types of information: i) whether the relationship is positive, null or negative; and ii) if the magnitude of the relationship is weak, moderate or strong. Statistical correlation cannot give us information about cause-effect between variables nor can be applied to variables presenting non-linear trajectories.

If endogeneity (loop causation) between two variables is present, statistical correlation has an advantage as compared to cause-effect methods, such as regression analysis. For instance, increasing figures on foreign investments (FDI) may cause increasing levels of domestic production (GDP) in a certain country. Also, increasing levels of domestic production in that country may cause FDI inflows to increase, characterizing a sort of loop causation. In such cases, it is convenient to use correlation analysis because it is not possible to isolate dependent and independent variables. Correlation could appropriately be applied just to track the paths of the two variables without taking causalities into account.

Formally, let Y_1, Y_2, …, Y_n and X_1, X_2, …, X_n be values of two quantifiable variables, with i = 1, 2, …, n a sample of n observations. Three types of correlation between Y_i and X_i can be derived from the reduced variables $U_i = \{Y_i - [(\sum Y_i) / n] / S_y$ and $V_i = \{X_i - [(\sum X_i) / n]\} / S_x$, where S_y and S_x are the sample standard-deviation of Y_i and X_i, respectively. If $\sum [V_i.U_i] > 0$, correlation between Y_i and X_i is positive; if $\sum [V_i.U_i] = 0$, correlation between Y_i and X_i is null; and if $\sum [V_i.U_i] < 0$, correlation between Y_i and X_i is negative. There is a forth type of correlation called spurious - even with an eventual strong positive correlation, e. g., between a variable 'number of street lights' and variable 'number of born female babies', both annually measured, it makes no sense to study this relationship. Theory, as relating key-variables in an appropriated and expected way, is the best devise to avoid us using spurious correlation.

The correlation coefficient 'r' is the operator for calculating correlation between two variables. It is obtained dividing $\sum [V_i.U_i]$ by (n – 1). This has to be so since $\sum [V_i.U_i]$ increases as the sample size 'n' increases. Plugging the reduced-standardized variables V_i and U_i given above into the correlation coefficient $r = \sum [V_i.U_i] / (n - 1)$, after some algebraic rearranging we get $r = \sum(x_i.y_i) / (\sum x_i^2.\sum y_i^2)^{1/2}$, where $x_i = (X_i - [(\sum X_i) / n])$ and $y_i = (Y_i - [(\sum Y_i) / n])$.

The values of the correlation coefficient 'r' range from -1 to +1, including zero which is the value for null correlation. The -1 value holds for perfect negative correlation and +1 for perfect positive correlation. For a clear treatment of the applicability of the coefficient of correlation, see Bobko [52].

We can discuss on the ranges for values of 'r' that correspond to different degrees of strength of the relationship between two variables. According to Choudhury [51], there is no agreement among scholars on the choice of the interval limits for 'r'. We will consider in the empirical section four intervals of values: [±0.9 ; ±1] very strong strength; [±0.8 ; ±0.89] strong; [±0.6 ; ±0.79] moderate; and [< ±0.6] a weak strength of relationship between any two variables.

BRIC Empirical Evidence: GDP and Economic, Social and Environmental Performances

We start the empirical section clarifying some issues. First, the aggregate GDP is treated here as a variable intentionally chosen to depict a country' growth performance. It is an *ex-anti* given indicator that we take without searching for causes to explain successes or failures in production growth. Causalities are not treated in this paper since the main purpose is to check the strength of the relationship between GDP paths over time and the trajectories of the selected economical, social and environmental performance variables. The GDP indicator is the evidence for the first of the two sides of the dilemma.

Second, sustainability, the other side of the dilemma, is empirically treated as the third pillar (environmental) of the sustainable development concept. Five environmental indicators were selected from the World Bank [53]. Two indicators of CO_2 emissions and three of consumption of energy sources will be used to investigate if there is a growth-sustainability dilemma. This will be done by tracking the trajectories of GDP and measuring their correlations with respect to the five environmental indicators selected. Correlations among GDP and the other sets of variables related to the first (economical) and second (social) pillars of sustainable development will be calculated, but we do not use them in relation to the dilemma.

BRIC's GDP Growth

This section aims to analyze the GDP figures for the BRIC countries from 1990 to 2011. The data set comes from the new version of the Penn World Table (Version 8.0) by Feenstra, Inklaar and Timmer [54].

In Fig. 1 we see that GDP is growing faster in China and India in the two decades and at a much slower pace in Russia and Brazil since the beginnings of the 2000s. China evidences an outstanding performance. Even during the hard years of the world financial crisis (2008-09), China just had a small downward change in the slope of its GDP curve, recovering in the last two years of the series. In absolute terms, China leads the whole two decades period, noting that by 1990 Russia's GDP was greater than China's.

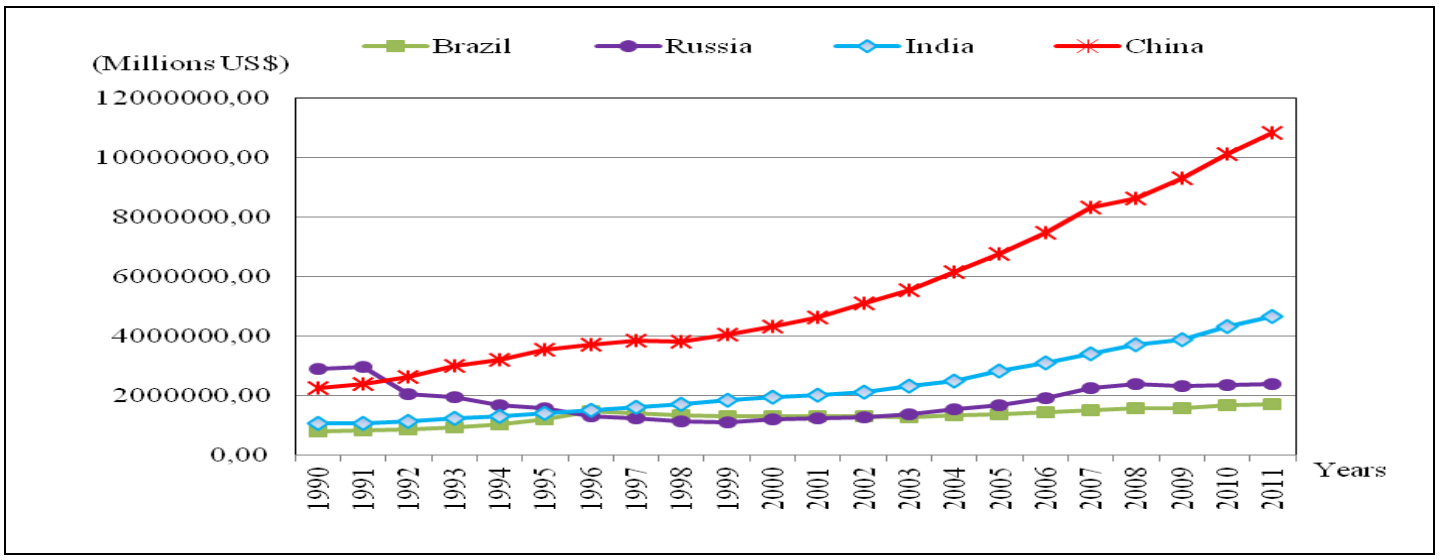

Fig. 1: GDP figures (millions of US$) for BRIC – 1990/2011
Source: The Penn World Table by Feenstra, Inklaar and Timmer (2013). Elaborated by the authors.

India, the second best in GDP growth, has had an outstanding performance since the last years of the 1990s, outperforming Brazil and Russia by 1998. In Fig. 1 we see the BRIC's GDP performance looking at the curves from the bottom-up: Brazil is the worse; Russia has performed a little better than Brazil since 2004; India, as it was said, is the second best; and China is the champion in GDP growth. Not only in levels but also in growth rates, as it is seen by the steeper slopes of its GDP curve since 2000,

China is an outstanding example of recent economic growth performance. It is an interesting exercise to check if this excelling production

growth has happened under reasonable standards of environmental performance.

Fig. 2 shows the growing economic importance of the two Asian countries in the 1990s and 2000s. From 1980 to 1995, Russia experienced a sharp decrease in its GDP share as a proportion of the world GDP, followed by Brazil, with a lesser intense reduction. These two countries have roughly maintained their shares between 1995 and 2008, with Russia presenting a minor relative improvement. This is consistent with the evidence in Fig. 1, as we saw that Russia presented a negative growth performance from 1990 until 1999, but outperformed Brazil in GDP growth by 2004.

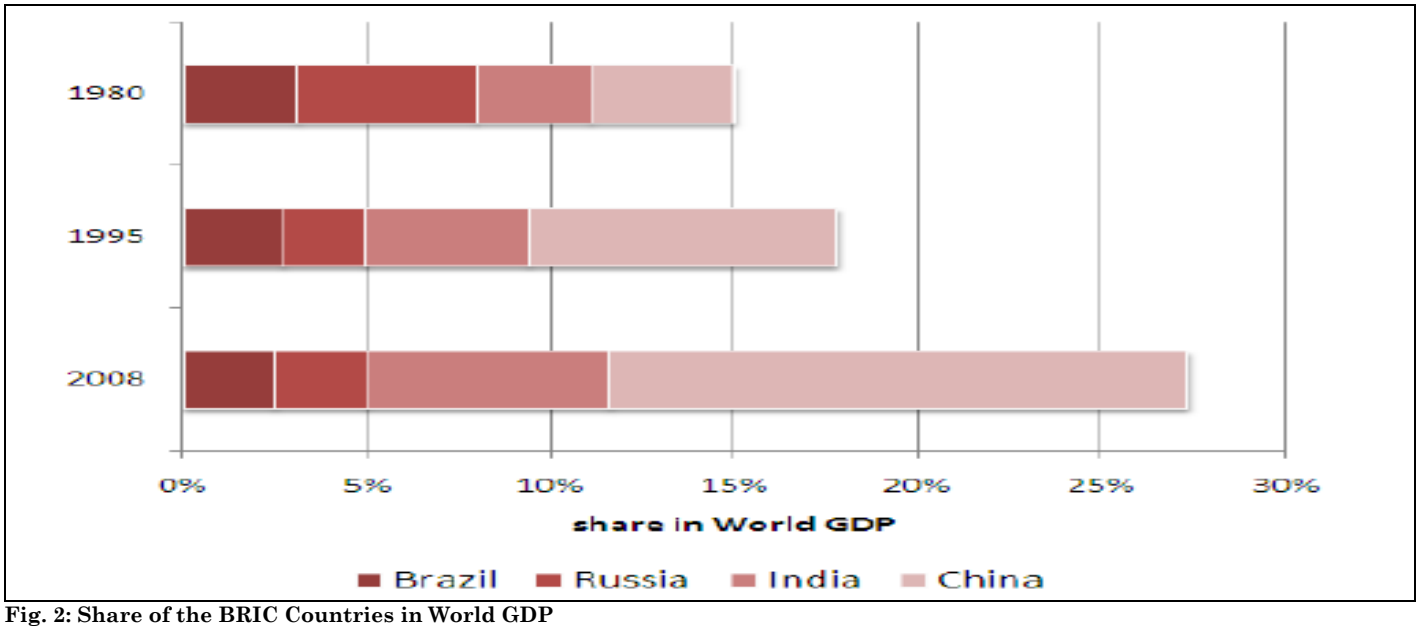

Fig. 2: Share of the BRIC Countries in World GDP
Source: Vries et al. (2012)

As Fig. 2 evidences, by 2008 China's GDP share is about the impressive 16% figure, while India's has reached 7% after an increase from about 3% in 1980 to 4,5% in 1995. This is also consistent with the evidence in Fig. 1: China is by far the leader in GDP growth, and India a follower, as an economy that has grown rapid since the mid-years of the 1990s.

BRIC's GDP and a Set of Economic, Social and Environmental Variables

A set of variables was selected from the World Bank [53] and the Penn World Table, Version 8.0, by Feenstra, Inklaar & Timmer [54]. The criterion for selecting three separated sets of indicators was to approach the three pillars of sustainable development (economical, social and environmental).

BRIC's GDP-Economic Performance Indicators

In this sub-section we selected 8 economical variables: employment (EMP), agriculture added value (AAV), industry added value (IAV), services added value (SAV), exports of goods and services (EGS), import of goods and services (IGS), high-tech exports (HTE), and foreign direct investments (FDI).

From Table 1 we see that the strength of the relationship between GDP and employment (EMP) is very strong [$r > 0.9$] in India and China – the relatively intensive factor labor has been highly absorbed as GDP increases in these two countries. The evidence for China is Vries et al. [55] who show that between 1997 and 2008 employment shares increased from 23% to 27% in industry and from 26% to 33% in services; and for India between 1991 and 2008, from 16% to 20% in industry and from 21% to 26% in the services sector. Vries et al. [55] affirm that reallocation of labor across sectors has had positive effects on China's GDP growth. Agriculture (AAV), industry (IAV) and services (SAV) added values show that the primary goods sector decreases and the services sector increases their importance as economic growth intensifies. Expected negative GDP-AAV correlations and positive GDP-SAV correlations are shown for India, China and Brazil.

Exports (EGS) and imports (IGS) of goods and services are very strong and positively correlated with GDP in India and just moderate and positively correlated [$0.6 < r < 0.8$] with China's GDP – India's relative trade engagement intensity, as a long-last capitalist economy, is a known event as compared with China's trade engagement, a recent advent related to its economic openness. Grossman and Helpman [9] predict that trade engagement is an important source of GDP growth. Correlations of GDP and

high-tech exports (HTE) are positive but just moderate for both India and China.

Foreign direct investment (FDI) is strong and positively correlated with GDP growth in Brazil

Table 1: BRIC - Correlation Coefficients for GDP x Economic Indicators - 1990/2011

	B	R	I	C
GDP x EMP*	0,778156891	0,8710801	0,977440847	0,943383868
x AAV	-0,77316199	0,397174672	-0,915371753	-0,890559959
x IAV	-0,805346865	0,476316847	0,630126045	0,487433575
x SAV	0,818050726	-0,469351107	0,892189958	0,877171302
x EGS	0,261568214	-0,407305958	0,96480163	0,797107866
x IGS	0,664699479	-0,254080575	0,979026302	0,742163706
x HTE	0,476379061	-0,661700084 [1]	0,710605433	0,796181213 [2]
x FDI	0,824077802	0,801623473 [2]	0,906013164	0,950955619

Source: The World Bank (2013). * The Penn World Table (2013). [1] 1996 – 2011. [2] 1992 – 2011. Authors' calculation.

and Russia and the strength of the relationship between these two variables sharply increases in India and China. The latter, as the leader in GDP performance, presents the highest GDP-FDI coefficient of correlation [r = 0.95]. It is a known fact that capital (FDI) flows to countries with good economic (GDP growth) performance. So it seems that the highest GDP-FDI correlations for India and China, countries with the best GDP performances, are not a coincidence. Empirical evidence on this result for China is Tian, Lin and Lo [56]; for a set of industrialized and developing countries Borensztein, De Gregorio and Lee [57]; and for middle and low-income economies Dabla-Norris, Honda, Lahreche and Verdier [58].

Table 1 evidences that India and China score as the best regarding the selected economic performance indicators. Brazil takes an intermediate position: GDP performance is similar to Russia's from 1996 to 2004 and relatively worse in the first years of the 1990s and the second half of the 2000s (see Fig. 1). Accordantly, consistent and significant correlation coefficients, with moderate strengths, can be seen in Table 1 for employment [r = 0.77] and imports of goods and services [r = 0.66].

The GDP-SAV and GDP-FDI correlations are strong [$\pm 0.8 < r < \pm 0.9$] with the right sign, showing that the services sector [r = 0.81] and foreign investments [r = 0.82] present strong strengths of relationship with production growth (GDP). It is interesting to note that the import substitution development strategy Brazil chose by the middle years of the 20th century can have influenced, even in the 1990s and 2000s, the weak strength of correlation between GDP and exports of goods and services [r = 0.26] and the moderate correlation between GDP and imports of goods and services [r = 0.66].

Russia presents the worse correlation figures for GDP performance and economic indicators. Only two indicators have positive and significant correlations: employment [r = 0.87] and foreign investments [r = 0.8]. All other correlation figures are weak and/or present an unexpected wrong sign.

To sum up, the evidence indicates that correlations between GDP and the whole set of economic indicators are consistent and significant only for India and China – the best two countries in GDP growth performance in the 1990s and 2000s (see Fig. 1).

BRIC's GDP - Social Performance Indicators

In this sub-section we selected 7 social variables: life expectancy at birth (LEB), population ages 65 and above (A65), mortality rate under 5 years of age (MR5), incidence of tuberculosis (ITU), improved water source (IWS), improved sanitation facilities (ISF), the index of human capital (IHC) — based on years of schooling by Barro and Lee [59] and returns to education by Psacharopoulos [60].

The evidence on the BRIC countries social indicators as correlated to GDP performance shows an interesting fact: for Brazil (strong strength; $0.8 < r < 0.89$), India and China (very strong strength; $r > 0.9$), all GDP-social indicators correlations show correct signs and significant magnitudes. Mortality rate under 5 years of age (MR5) and incidence of tuberculosis (ITU) are expected to present negative correlations as they do. Decreases in children mortality and incidence of tuberculosis are very strong in China and India, strong in Brazil and very weak in Russia [r = -0.32].

As in the previous sub-section where we analyzed the GDP-economical performance indicators, India, closely followed by China, presented the best social variables figures.

Russia again is the relatively worse country in social indicators performance, presenting weak

Table 2: BRIC - Correlation Coefficients for GDP x Social Indicators - 1990/2011

	B	R	I	C
GDP x LEB	0,897063242	0,755596639	0,953634112	0,941046262
x A65	0,876866908	-0,272613915	0,979401829	0,974253724
x MR5	-0,8911819	-0,32000664	-0,949231892	-0,960852663
x ITU	-0,896510376	-0,624114116	-0,941132198	-0,934857954
x IWS	0,896728902	0,036755216	0,958515618	0,947037087
x ISF	0,895930058	-0,036368094	0,964944722	0,957717532
x IHC*	0,874654845	-0,148592442	0,965276579	0,938545884

Source: The World Bank (2013). * The Penn World Table (2013). Authors' calculation.

and/or unexpected wrong signs. Even for the index of human capital (IHC), which is unambiguously expected to positively influence economic growth, correlation for GDP-ICH is negative but insignificant [r = -0.14].

Evidence on the direct relation between GDP growth and education is abundant. Fleisher, Li, and Zhao [61] show that human capital positively affects output growth in China; Lee and Malin [62] found that about 11% of GDP growth in China, from 1978 to 2004, was accounted for by increased education; Caselli and Ciccone [63] develop an upper bound on the increase in output that can be generated by more schooling; and Castelló-Climent and Mukhopadhyay [64] assert that a higher proportion of India population completing tertiary education is expected to have a strong and positive effect on India's GDP growth.

To sum up, the evidence indicates that correlations between GDP and the whole set of social indicators are consistent and significant for Brazil, India and China. Again, from Fig. 1 we see that India and China are the best countries in GDP growth performance in the 1990s and 2000s and also the best in the social performance indicators (see Table 2).

BRIC's GDP - Environmental Performance Indicators

In this sub-section we selected 5 environmental indicators: energy use (ENE_c), fossil fuel energy consumption (FFE_c), road sector gasoline fuel consumption (GAS_c), CO_2 emissions (CO_2), and CO_2 emissions from transport (CO_{2t}). High positive figures (close to +1) for calculated correlations between GDP and the environmental performance indicators mean that environmental degradation is increasing almost at the same pace as GDP grows.

From Table 3 China is the worse country in environmental performance, with coefficient of correlations very close to +1 in all five selected indictors. It is closely followed by India, the second in environmental depletion, the difference being just the correlation figures for CO_2 emissions from transport (CO_{2t}) with r = 0.9 for India and r = 0.99 for China.

Russia is the relatively best country in environmental performance, followed by Brazil. The only very strong strength of relationship for Russia is that between GDP and electricity power consumption (ELE_c), with r = 0.93. CO_2 emissions (CO_2) in Russia is just moderately correlated with GDP, with r = 0.66. Energy use (ENE_c), road sector gasoline fuel consumption (GAS_c), CO_2 emissions from transport (CO_{2t}) present high correlation figures (strong strength) in Russia, but of relatively less intensity as compared with the figures for China and India.

Table 3: BRIC - Correlation Coefficients for GDP x Environmental Indicators - 1990/2010

	B	R	I	C
GDP x ENEc	0,887959471	0,897998774	0,990927838	0,991876407 [2]
x FFEc	0,220184928 [2]	0,223180174 [2]	0,940600441 [2]	0,967299134 [2]
x GASc	0,908920679	0,826684554	0,990849306	0,990917303
x CO_2	0,926596246	0,665977778 [1]	0,98423063	0,984534009
x CO_{2t}	0,932217039	0,894832457	0,90189607	0,992422443

Source: The World Bank (2013). Authors' calculation. [1] 1992 – 2010. [2] 1990 – 2011.

Brazil has also high GDP-environmental indicators correlations, but with relatively smaller magnitudes if compared to India and China, the leaders in environmental degradation, and, as Fig. 1 showed, the leaders in GDP growth.

A word on the growth-sustainability dilemma is needed now. The negative environmental performances of China and India let us to state that the dilemma is strongly presented for these two countries. They are the best in GDP growth and the worse ones in environmental performance. Brazil also presented a bad performance on the environmental indicators. So the dilemma, of a second order importance, is also a reality for this country. Russia, the second worse country in GDP performance (Brazil is the worse) ranks first, with reasonable environmental standards. China, the leader in GDP growth, scores as the worse, sided by India, in environmental performance.

Theoretically, these results were predicted by the production-cum-environment models in section 1 – more pollution as waste generation and more natural resources consumption (decreasing environmental standards) are expected if the pace of physical capital accumulation (production) speeds up or does not slowdown (resulting in increasing levels of GDP).

Conclusion

Many countries have been facing difficulties in pursuing sustainability. Increasing interest in sustainable development has led to socio-political as well as academic debates whose main purpose is to find means of eliminating obstacles to sustainability. Brazil, Russia, India and China are important economies that in the last two decades have become strong, both economic and politically.

Due to the importance of these countries as emerging economies, this paper analyzed the growth-sustainability dilemma, focusing on BRIC's economic, socio and environmental performance from 1990 to 2011. The empirical evidence showed that GDP growth has occurred with advances in sustainable development, mainly considering the economic and social pillars.

Summing up the main results taking into account the three sets of economical, social and environmental performance indicators, we say that performances on the economic variables were reasonable for all countries, except Russia, with India leading China for the measured correlations on GDP-economic indicators [except for GDP-HTE (high-technology exports) and GDP-FDI (foreign direct investments), where China scored better]. GDP correlations against the selected economic indicators showed Russia presenting the worse performance, India and China presenting very good performances and Brazil reasonable results.

On social indicators, all countries, again except Russia, presented good standards, with India and China leading. Based on these results, we can say that GDP growth has been related to reasonable socioeconomic improvements in the BRIC countries, except in Russia, and at least for the economic and social pillars of sustainable development the results are satisfactory for India, China and Brazil. Economic and social improvements have happened in three out of the four emerging economies investigated.

What to say about the environmental standards? As it was seen, Russia seems to be the relatively more sustainable-based country, despite its positive and significant correlations for all GDP-environmental indicators (except for the correlation GDP-CO_2, with a moderate $r = 0.66$). China is the leader in environmental degradation, as evidenced by the GDP-environmental indicators correlations, closely followed by India. Brazil scores as an average player on environmental degradation, a position compatible with its status of a weak GDP performer. Russia, the best on environmental standards, is the second worse in GDP performance.

Theoretically, these results were predicted, as already said, and as the evidence on the BRIC countries shows the dilemma is strongly present in China and India – more pollution as waste generation and more natural resources consumption (decreasing environmental standards) are directly and very strongly related with increasing levels of GDP. Brazil is also depleting the environment, but due to its less intense production growth, the magnitudes of the GDP-environmental performance indicators correlations are relatively less intense. Russia, whose GDP performance in many years of the 1990s and 2000s mirror Brazil's, the evidence on environmental degradation is strong but relatively less intense than those of the other BRIC countries.

Based on the main result – the growth-sustainability dilemma is present in all four countries, just with differences in intensities – we end the paper with a concern on how feasible is the sustainability perspective for the BRIC countries in a near future. If these emerging countries prospect an intensification of their production potentials, as it is expected for the next coming years, what will be the expectations

for their environmental standards? The positive results on the economic and social performance indicators, improving the patterns of the first and second pillars of sustainable development in the BRIC countries (excepting Russia), have to be paired with desirable levels of environmental commitments.

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