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Impact of infrastructure expenses in strategic sectors for Brazilian poverty

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Abstract

This paper analyzes the impact of infrastructure investments in the reduction of poverty in Brazil, controlled through other determinants such as economic growth, income inequality, average schooling years, unemployment rate and state budgets from 1995 to 2011. A model for a dynamic panel data, estimated by the generalized method of moments (GMM) in two steps as developed by Arellano-Bond (1991) and Blundell-Bond (1998) found among other conclusions, a significant inverse relation between public investment in infrastructure and poverty. The Granger causality test for panel data proposed by Hurlin and Venet (2001, 2004) and Hurlin (2004, 2005) reinforced results validation.

JEL classifications: H54; I30

Keywords: Poverty; Infrastructure; Dynamic panel

Resumo

O trabalho tem como objetivo principal analisar o impacto dos investimentos em infraestrutura nos setores estratégicos da economia (transporte, energia, comunicação, saúde e saneamento) na redução da pobreza controlando por outros determinantes tais como crescimento econômico, desigualdade de renda, anos médio de estudo, taxa de desemprego e receitas governamentais orçamentárias para os estados brasileiros, no período de 1995 a 2011. Um modelo para dados em painel dinâmico, estimado pelo método de momentos generalizados-sistema (MMG-S) em dois passos, desenvolvido por Arellano-Bond (1991) e Blundel-Bond (1998), detectou, entre outras conclusões, uma relação significante entre os investimentos públicos em infraestrutura e pobreza, sendo estes uma ferramenta eficiente no combate desta. Os outros determinantes investigados desempenham um papel importante

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na dinâmica da pobreza no Brasil. O teste de causalidade de Granger para dados em painel, proposto por Hurlin e Venet (2001, 2004) e Hurlin (2004, 2005) valida os resultados.

Palavras-chave: Pobreza; Infraestrutura; Painel dinâmico

1. Introduction

Historically speaking, all expenses in Brazilian infrastructure have always been the responsibility of the public sector. In the nineties, however, partnerships between the public and private sectors enabled the beginning of significant participation of national and international private companies through privatizations in the telecommunications sector and part of the energy business, road and railroad concessionaries, etc. However, despite these changes, the State continues to be the main responsible agent for the supply of infrastructure.

Seeking to discuss the role of infrastructure in poverty reduction, it must be said that more access to infrastructure services also affects the materialization of the so-called "Millennium Development Goals" (MDG) Brazil is involved in. The contribution of infrastructure to the Millennium Development Goals (MDG) is reflected in the increase in productivity and wellbeing among poor people, thus improving their access to local markets and other regions, optimizing the coverage and the quality of services offered through the improvement of education, health, transportation services, energy, information technology and basic sanitation.

The infrastructure supply is a vital component of the incentive to national economic growth, both for its potential to generate employment and for its influence in all economy sectors. In this sense, it improves economic activity and helps reduce persistent poverty. Additionally, wide access to infrastructure contributes to reduce inequality (Sílvia and Triches, 2014; Bertussi and Ellery, 2012; Mussolini and Teles, 2010; Calderon and Serven, 2004; Ferreira and Malliagros, 1998).

Adequate infrastructure is a necessary condition for economic development. Therefore, any growth strategy planned to help the poor must necessarily include the promotion of investment in infrastructure in order to allow wider population access to the positive externalities created by such investments (Hirschman, 1958; Datt and Ravallion, 2002).

An adequate infrastructure is a necessary condition for economic development. Therefore, any growth strategy that involves helping the poor must necessarily contemplate the promotion of infrastructure investments, seeking to allow this population segment a better access to the positive externalities generated by adequate infrastructure.

According to the Inter-American Development Bank (IDB, 2000) it is possible to define infrastructure as a set of engineering structures and facilities that are the necessary basis for the development of productive activities such as services, policies, social and personal activities. The regions that directly benefit from infrastructure services achieve positive externalities, attracting industries and human capital, thus increasing productivity and stimulating economic growth.

Among international works that empirically tested the role of infrastructure in the fight against poverty, we should mention those of Jacoby (2000), Runsinarith (2008), Roy (2009), Ogun (2010), Seetanah et al. (2009), Escobal and Ponce (2001) and Aparicio et al. (2011) among others.

In the local environment, economics literature on the impact of direct public investments in infrastructure for poverty reduction purposes is mainly covered by the works of Cruz et al. (2010) and indirectly, by the Kageyama and Hoffmann study (2006).

With this perspective, considering the temporal effect of poverty and using state-provided data, this article analyzes if the results of infrastructure investment policies have affected the dynamics of poverty in Brazil from 1995 to 2011. For this purpose, we applied a dynamic panel data model that uses the Generalized Method of Moments (GMM) developed by Arellano and Bond (1991), Arellano and Bover (1995) and Blundell and Bond (1998). Additionally, the Granger Causality Test was applied for Hurlin and Venet panel data (2001, 2004) and Hurlin (2004, 2005) which validated results by revealing that infrastructure is an efficient tool to fight poverty. This test points at both the existence of this tool and the causality link between poverty and infrastructure.

The GMM methodology enables to solve the problem of endogeneity in econometric models, as well as to detect the effects of possible omitted variables and measurement errors. In this model, we intend to verify the correlation between poverty and infrastructure, which is measured through the State's public expenses per capita in strategic areas of the economy (energy and mineral resources, transportation, communications, health and sanitation). This relation is controlled by other poverty determinants, such as the gross domestic product (GDP) per capita, average schooling years, income inequality, unemployment rate and the State budgets.

The most common way to measure poverty, because of its simplicity, is the setting of a poverty line, in other words, an income level below which people are classified as poor. The poverty line used is made available by the IPEA (Institute of Applied Economics Research) and its value is equal to half minimum monthly salary according to prices of September 2009. The calculation of this line follows the Corseuil and Foguel method (2002). The indicator used to measure absolute poverty was the proportion of poor people.

The poverty line applied in this article was made available by the Institute of Studies on Labor and Society IETS, for several Brazilian states. This line doubles the indigence line and it is defined as the financial value necessary for an individual to purchase minimum calorie consumption food. The indicator used to measure absolute poverty was the proportion of poor individuals.

Among other important findings, the main one was that public investment in public infrastructure provoked a significant impact on poverty reduction. As for the other determinants, such as the increase in years of schooling, State budgets and the reduction of unemployment, they also contributed to decrease poverty incidence. The same happened with regards to the State GDP per capita, however this impact has been lower than that of income inequality. This fact may be due to the high income concentration found in Brazil, which in a certain way amortizes the effects of economic growth.

The remaining of the article is organized in seven sections. Section 2 reviews the relation between public investment in infrastructure and poverty. Section 3 analyzes poverty determinants. The fourth section introduces a discussion on the database and the construction of model variables. In the fifth section we specify the econometric model and discuss the Granger Causality Test for panel data. In the sixth section, estimated econometric data and the Granger Causality Test data are analyzed. The last section draws the final conclusions.

2. Theoretical and empirical aspects of the relation between poverty and infrastructure

The effects that infrastructure exerts on poverty have been the object of a series of studies in economics literature specialized on the subject. In general, it is supposed that the provision of adequate infrastructure is a key element to reduce poverty, as it triggers a direct effect in the improvement in employment rates and wages when the economy growths and becomes more competitive.

In its theoretical studies, Hirschman (1958) states that public investment in infrastructure is vital for the social and economic development of a country, once it provides an attractive environment for private investments, thus making services cheaper and more competitive and therefore supporting all other economic activities.

The infrastructure components that exert the highest influence on the systemic competitiveness of companies are related to the offer of energy, transportation and telecommunications. The offer of these components plays a key role in those states that offer it at low cost in an efficient, regular and reliable way. According to Hirschman (1958), infrastructure is composed of basic services such as the judiciary power, education, public health, transports, communications, water and electricity supply and the agricultural support in services such as irrigation and drainage.

With regards to international empirical evidence, there are several works that estimate the impact of infrastructure in poverty reduction in many countries. A case study with data on Nepal's population living standards was developed by Jacoby (2000) for the years 1995 and 1996. The study found that the construction of market access roads offered substantial benefits to poor families. However, such improvement was not consistent enough to significantly reduce income inequality.

The role of roads as one of the factors that contribute to affect poverty incidence was studied by Kwon (2001) in 25 Indonesian provinces between 1976 and 1996. With the use of instrumental variable techniques, results showed that the significant effect that roads exerted on poverty reduction was higher in provinces with good road access than those that did not have such infrastructure.

In another study on Indonesia, Balisacan and Pernia (2002), used disaggregated panel data for 285 districts from 1993 to 1999. They noticed the significant importance of roads on the average poor people performance. Following the same research line, Dercon and Krishnan (1998) used data collected from rural Ethiopia in 1989, 1994 and 1995 to evaluate determinant factors of changes in poverty levels and detected that families with higher human capital and better road access presented lower poverty levels. In Peru, Torero et al. (2001) analyzed the significance of infrastructure (drinking water, sewage system, electricity and telephone) on poverty in the years 1985, 1991, 1994 and 1996. Obtained results showed that having a telephone line contributed to reduce urban poverty more than other infrastructure services, although this type of infrastructure has no significant effects in rural areas. In another Peru study on the evolution of poverty through time and its determinants from 1997 to 1999, Herrera and Roubaud (2002) demonstrated that access to public infrastructure services significantly reduces the probabilities of falling into "permanent" poverty. Besides, in the case of families that have always been poor, the access to these services increases their chances of leaving poverty.

Fan et al. (2002) analyzed the effects of different types of public expenses on economic growth and rural poverty in Chinese and Vietnamese provinces, finding that public expenses on rural roads have a big impact on poverty incidence. The research showed that poor families living in rural municipalities with paved roads have 67% more chances of overcoming poverty than those living in communities without this kind of infrastructure.

Confirming these empirical evidences on the relation between poverty and infrastructure, Warr (2005) proved that in the years 1997/1998 and 2002/2003, the reduction of rural poverty in Laos was attributed to the improvements in road accesses.

The methodology of static and dynamic panel data is used in a study carried out by Seetanah et al. (2009) to measure the relevance of infrastructure on urban poverty in a 20-country sample collected between 1980 and 2005. Government expenses on roads and communications are applied as an infrastructure *proxy*. In both models, they discovered that transports and communications are efficient instruments to combat poverty in urban areas. Applying the Granger Causality Test, they identified a reverse causality between poverty and infrastructure.

In a study carried out in 91 countries including Brazil, Rajkumar and Swaroop (2008) used a cross-section data on government expenditures on health and education in 1990, 1997 and 2003, verifying the existence of a reverse causality between poverty and health infrastructure. They corroborated that when a government faces a situation of poverty and health deterioration among its citizens, or even in critical education situations, the State tends to increase expenses in these areas.

Another study that used public expenses as infrastructure *proxy* for 25 Indonesian provinces from 1976 to 1996 was developed by the Asian Development Bank and the Resources Center for Economic Development (1999). The study proved that the reduction in poverty rates was the result of investments in roads, health, agriculture, education, sciences and technology. By applying panel data models (fixed and random effects) to reflect the impact of different infrastructure types (access to water, sewage system, electricity and telephone) on domestic expenses in Peru for the 2007–2010 period, Aparicio et al. (2011) verified a differentiated and significant impact of infrastructure on the reduction of transient and chronic poverty, depending on the geographical area (urban or rural), the sex and the family head.

A study of 73 Philippines provinces developed by Balisacan (1999) with data from 1988 to 1997 showed that changes in access to electricity were strong and positively correlated to the reduction in poverty levels. Another research developed in the Philippines by Balisacan and Pernia (2002) in the eighties and nineties corroborated that electricity positively affected the income of the poor.

Runsinarith (2008) found significant impacts of mobile telephones, electricity, irrigation and roads on poverty incidence through the application of quantile regressions in Cambodia for the year 2006. He concluded that mobile technology was the infrastructure with the highest impact on poverty reduction, followed by electricity, roads and irrigation.

With the development of two infrastructure indexes (physical and social) created through the method of main components, Roy (2009) detected a strong negative correlation between the human poverty index and physical infrastructure (roads, electricity, irrigation projects, etc.) and social infrastructure (hospitals, schools, etc.) in India for the period 1981–2001. On the other hand, Ogun (2010) based on data related to the 1970–2005 period found that the development in social and physical infrastructure significantly reduced poverty in urban areas of Nigeria.

Likewise, Datt and Ravallion (2002) estimated the determinants for differences in poverty reduction rates among Indian states for the period 1960–1994. One of the main facts is that State government expenses aimed at economic development exerted a great impact on poverty reduction, even when controlled by agricultural and non-agricultural productivity changes in a temporary tendency. In a more detailed study, Datt and Ravallion (1998) proved that the Indian states with the best infrastructures and human resources boasted significantly higher poverty reduction levels.

Ghosh and De (2000), evaluated physical infrastructures in south Asian countries in the eighties and nineties, demonstrating that differentiated amounts of physical infrastructure were responsible for the growing regional disparity in southern Asia.

By using a non-balanced panel of 121 countries from 1960 to 2000, Calderon and Serven (2004) applied quantitative infrastructure indexes and quality indicators that demonstrated positive and significant infrastructure stock effects on the income level and economic growth of these countries. These authors sustain that the development of infrastructure favors a better income distribution and consequently, a reduction in poverty levels.

The national literature on the importance of infrastructure in the reduction of poverty is very rich. We can highlight the works of Cruz et al. (2010), who based on data obtained from 1980 to 2007 concluded that federal and state public expenses on education, health and physical capital (roads and energy) are extremely relevant for the income generation and productivity growth, which somehow allow to reduce poverty levels.

In a multidimensional analysis of poverty in Brazil for the period from 1990 to 2004, using data from the National Research per Sample Domiciles (PNADs) Kageyama and Hoffmann (2006) verified that there was an improvement tendency in infrastructure conditions, being this trend largely responsible for the poverty reduction.

Bertussi and Ellery (2012) investigated the impact of public expenses in transport based on the economic growth of Brazilian states between 1986 and 2007, using panel data. These authors verified that the public investment in the transport sector provoked a positive and statistically significant effect on the long-term economic performance of Brazilian states. Besides, this investment potentially contributed to the reduction of income inequality among different states.

When analyzing the effects of infrastructure on Brazilian productivity from 1950 to 1995 from an empirical perspective, Ferreira and Malliagros (1998) estimated product and productivity elasticity with regards to the capital and the infrastructure investment. They estimated the unbundled impact of infrastructure expenses in five sectors (electricity, telecommunications, railroads, highways and ports) on the GDP and the productivity of private factors. Among the main results obtained, they verified a strong relation between infrastructure and the long term product, also corroborating that the total productivity of factors is not Granger-caused by productivity, but rather, the other way round.

Likewise, Mussolini and Teles (2010) analyzed the relation between infrastructure and total productivity of factors, which was considered the main long-term growth trigger from 1950 to 2000. Results were opposite to those of Ferreira and Malliagros (1998). This means that infrastructure improvement for a certain private capital stock may cause in the Granger sense, the total productivity of factors. However, Sílvia and Triches (2014) analyzed effects of government expenses in the infrastructure, communications, transport, health and basic sanitation sectors in the Brazilian economy product from 1980 to 2005. Among the main results obtained, public expenses in infrastructure in the analyzed sectors showed positive and statistically significant impacts on the growth of Brazilian product during the studied period of time.

3. Poverty and other determinants

3.1. Relation between poverty, economic growth and income inequality

Several national and international empirical works confirm the common sense idea that economic growth helps poverty relief efforts in two ways: by expanding the number of jobs and by increasing the real wages paid to the workers. Poverty reduction depends both on growth rates as well as on decreasing inequality levels.

For example, Anderson (1964), Thornton et al. (1978) and Hirsch (1980) analyzed this relation through a trickle-down economic growth model for the United States. The basic concept is that although growth primarily benefits people in the highest income distribution pyramid, a robust growth tends to help those who are in the lowest income distribution level as well. However, a number of recent studies suggest that the economic expansion that America experienced in the eighties had no statistically significant effect on aggregated poverty. Blank (1993) and Formby et al. (2001) affirm that aggregated poverty was less sensitive to the American economic expansion of 1980 than to the one enjoyed in 1960.

Contrary to this perception, Enders and Hoover (2003) examined the effects of economic growth and other determinants in poverty rates through non-linear models, using two techniques: the Threshold regression and the Fourier approximation. Through the analysis of the 1961/1996 period, they demonstrated that the American economy expansion of 1980 did have an important role in poverty reduction.

Unlike other authors such as Ravallion and Huppi (1991), Datt and Ravallion (1992) and Kakwani (1993) do take into consideration poverty and its causes. They are particularly careful to distinguish the effects of growth on poverty reduction as well as distribution variations.

According to Ranis and Stewart (2002) when analyzing data from several Latin American countries, it is clear that economic growth is not always enough to eliminate poverty. In the sixties, seventies and eighties in Brazil, for example, there was a strong bias about being pro-economic growth but with a low human development.

In the nineties, Kageyama and Hoffmann (2006) affirmed that Brazil had entered a "vicious circle" in which low human development standards started to limit economic growth. Contrary to what happened in the eighties, in the nineties there was a general increase in social expenses in Latin America including Brazil, which could potentially prepare the path for new growth standards in the current decade.

Economic growth is fundamental to reduce poverty but Barreto (2005), Hoffmann (2005), de Lima et al. (2003) and Menezes and Pinto (2005) highlight that its effects are multiplied on the poorest when accompanied by redistribution policies.

For Gafar (1998), growth is a necessary condition to reduce poverty as it increases employment opportunities, the standard of living and real wages; however this is often not enough, as when growth is urban-biased with intensive capital and qualified employment concentration, poverty can increase even with a growth in the per capita *GDP*.

Economic growth opportunities, according to Rocha (2006) tend to have concentrating effects, as they imply the application of modern technologies associated to the use of qualified manpower, which requires compensatory measures to avoid an increase in inequality, as well as initiatives to promote the reduction of absolute poverty.

The persistence of absolute poverty in the country is, according to Rocha (2006) originated by the inequality existent when yield is considered. He remarks that absolute poverty may be reduced both through the increase in income as well as through the improvement in its distribution, however there is a consensus that the focus must be on reducing inequality. This is because income growth without inequality reduction means transferring the elimination of absolute poverty in the country to a distant future.

Barros and Mendonça (1997) and Barros et al. (2007), using PNAD data from 1993, verified that a reduction in poverty levels within a society requires economic growth or a decline in inequality levels. This fact is certainly one of the main reasons why the goals of public policies are focused on the search for both growth and equality. They notice an almost linear relation between economic growth and poverty reduction.

In another, the referred authors, when analyzing the period between 2001 and 2005, verified that the income growth of the poorest 10% reached 8% per year, which resulted in a remarkable poverty reduction that included a decline in inequality levels. They also observed two desirable transformations in the Brazilian income distribution: there was growth (however modest) and inequality decreased significantly (the Gini coefficient fell 4.6%). The novelty during this period was that contrary to other historic episodes of dramatic poverty reduction, this time, the driving force for this improvement was not growth but a strong decrease in inequality levels.

Neder and Silva (2004) developed methodological applications to estimate poverty rates and income distribution in Brazil's rural areas based on PNAD data from 1995 to 2001. Their results also confirmed a significant reduction in income concentration in rural areas in most of the analyzed states.

Moreira et al. (2010) evaluated the effect of growth and inequality components in poverty variations for Brazilian states between 1996 and 2007. They analyzed the existence of barriers originated in the inequality and poverty conditions that may impede a *per capita* income growth in Brazilian states. They verified that variations in state poverty dynamics continue to be more sensitive to income distribution than to growth, reflecting the persistent regional disparities observed.

On the other hand, Marinho and Araújo (2012) based on panel data for Brazilian states in the 1995–2009 term, analyzed the impact of economic growth variations and income inequality on poverty alterations in Brazil. Estimated results concluded that the income growth related to poverty reduction is lower when the initial development level is low and that the same result is seen when the initial inequality level is high.

3.2. Relation between poverty and average years of schooling

The models of economic growth have highlighted the importance of the human capital stock for economic growth and consequently, for poverty reduction. Access to good quality education helps the poor obtain a better labor market positioning, thus being able to break the poverty circle.

Shultz (1973), one of the pioneers of the human capital theory, affirms that nowadays people are investing more and more in themselves as human assets and that such human investments are constituting a growing influence on economic growth, as the basic investment in human capital starts with formal education and training. Therefore, education has as its fundamental role, the development of skills and knowledge seeking to increase productivity, promoting the obtainment of cognitive skills. Finally, the higher the productivity gain, the bigger the income a person will get, thus improving its social position.

For Enrenberg and Smith (2000), the improvement in education levels result in productivity growths, which also raise real wages in agreement with the human capital theory. This way, regions with a high human capital stock boast a higher average salary than the others. Besides increasing wages, knowledge concentration generates positive externalities for the region as growth standards become more dynamic, inducing the arrival of new investments and the dissemination of new knowledge and skills.

Reis and de Barros (1990) and Queiroz (1999) state that the education variable measured by years of schooling can better explain differences in individual performance among different regions through a certain period of time. A concentration of human capital stock tends to benefit the most developed cities (with more formal education) to the detriment of the less developed municipalities (less educated) generating an ever-growing gap in regional wage levels.

A human capital analysis through education in Brazil, as carried out by Vilela (2005) demonstrated that during the 1991–1996 quinquennium, regional education participation in the Human Development Index (HDI) was very high: 62% in the Midwest, 60% in the Southeast, 59% in the Northeast, 54% in the South and 42% in the North. These figures evidenced the important contribution of this variable in poverty reduction among Brazilian regions.

Using PNAD data from 1999, Rocha (2006) noticed that education indicators in Brazil provide evidence of the correlation between low educational level and poverty. For adult individuals (25 or over) the disadvantage that a low schooling level represents in terms of poverty incidence was evident, as the percentage of poor people declines monotonically according to the schooling level. Only 2.1% of individuals with some sort of higher education are poor.

Marinho et al. (2011) analyzed the impact of income transfer programs on poverty in Brazil, controlled by other determinants such as economic growth, income inequality and mean years of schooling, percentage of families led by women and male unemployment rate from 2000 to 2008. Among the most relevant results, they found that an increase in the mean years of schooling contributed to reduce poverty during the analyzed period. They highlight that the effect of education policies on poverty levels is relatively higher on the proportion of poverty than on those considered extremely poor. They also verified that income transfer programs do not significantly affect poverty reduction.

3.3. Relation between poverty, unemployment rates and government revenues

There is a general consensus in traditional economics literature that unemployment is positively related to poverty.

When analyzing poverty determinants in the United States, Formby et al. (2001), verified that the variation in the male unemployment rate has a significant impact on poverty when the linear regression model is applied. However, Enders and Hoover (2003) found that using the same database, this effect is only significant if non-linear regression models are used.

For this same economy, Hirsch (1980) analyzed the reasons why poverty only experienced a slight decline even with the strong economic growth in America in 1980. One of the explanations was that even when a reduction in the unemployment rate benefited the poorest, a decline in real wages more than compensated for the prior effect. The inclusion of the unemployment rate in his model controlled the effect of the business cycle.

Analyzing data from the 2000 Census, Barbosa (2004) suggested that there are unemployment rate differences between the poor and the non-poor in the different geographical areas throughout Brazil; however they appear to be higher in metropolitan areas. He noticed that poverty and unemployment are highly related, that is, poverty can be explained through unemployment or the structure of the labor market.

Another study that relates the number of unemployed people to poverty is the one carried out by Machado et al. (2003). These authors affirm that the successive financial crises suffered by the country during the nineties unleashed unemployment and a working relations weakening phenomenon, which contributed to widen social poverty and inequality in the state of Minas Gerais. However, they highlight that there was a labor market evolution from 1996 to 2003 and identify demographic groups characterized by significant poverty vulnerability.

Seeking to measure the relevance of infrastructure on urban poverty, a sample of 20 countries for the period between 1980 and 2005 was elaborated by Seetanah et al. (2009), who verified that education, inflation, government revenues, paved roads, communications and the unemployment rate significantly impacted on the reduction of urban poverty.

Another relevant result was that when the government revenues are increased in 1%, urban poverty declines 23%. It is worth highlighting that this is one of the few studies that relate poverty to government expenses.

4. Database descriptions and analysis

The database used was obtained from PNAD, IPEADATA and FINBRA for the different states and the Federal District of Brazil, comprising the 1995–2011[1] period of time. It is worth highlighting that the Arellano and Bover (1995) and Blundell and Bond (1998) models, described in detail in the next section are valid for a small temporal dimension in which observational units must be considerably higher.

The absolute poverty indicator applied was the proportion of poor people (P_0) who belong to the class proposed by Foster et al. (1984). For the calculation of such index, the poverty line defined by IPEA was considered according to prices of September 2011, which considers the value of the line equal to half minimum monthly salary. To update family income,[2] the INPC (National Consumer Prices Index—Restricted) was applied, as published by IBGE and corrected through the methodology suggested by Corseuil and Foguel (2002). This poverty index is calculated based on the following equation: $P_0 = q/n$, where q is the number of poor individuals (number of persons with a per capita income below the poverty line) and n is the population size.

Despite being important and easy to calculate, this indicator only describes the poverty extension, being insensitive to the poverty intensity. This measurement is not altered by reducing the income of an individual below the poverty line, or if such income grows but does not reach the poverty line. The proportion is also insensitive to the income distribution among the poor, not being altered when income is transferred from a very poor individual to another one who is less poor.

The unemployment rate was calculated based on the relation between the unemployed population and the economically active sector as obtained from PNADs data.

The data obtained from IPEADATA was: state GDP per capita at constant prices in Brazilian reais for 2011 deflated by the implicit national GDP deflator, the average schooling years for people aged twenty-five or more and the Gini index as a measurement of income inequality.

State government budget funds and public State infrastructure expenses per capita in the strategic economy sectors (energy and mineral resources, transportation, communication, health and sanitation) were collected from FINBRA and deflated by the General Price Index—Internal Availability (IGP-DI) based on the year 2011. A proxy for the infrastructure index was created with a per capita average of State expenses in these strategic sectors.

5. Econometric model

This section introduces the empirical model through which the relation between poverty and infrastructure controlled by other determinants is analyzed. The econometric specification is based on the assumption that common poverty tends to be perpetuated and/or affect its future development. The empirical evidence of this phenomenon for Brazil can be observed in the study performed by Ribas et al. (2006), where the authors demonstrate that poverty in Brazil is essentially chronic.

Therefore, taking into consideration this evidence together with other poverty determinants, the adequate econometric model to analyze these interactions must be a dynamic panel data model. Consequently, for Brazilian states and comprising the period from 2000 to 2009, the model is defined as follows:

$$P_{it} = \beta_0 + \beta_1 P_{it-1} + \beta_2 \text{inf}_{it} + \beta_3 pib_{it} + \beta_4 aem_{it} + \beta_5 gini_{it} + \beta_6 regov_{it} + \beta_7 des_{it} + \eta_i + \varepsilon_{it} \quad (1)$$

[1] Data for the year 2000 was generated through interpolation (arithmetical average) using PNADs from 1999 and 2001. Data for 2000 and 2010 was generated by interpolation (arithmetic mean) using PNADs from 1999 to 2001 and 2009 to 2011 respectively.

[2] As monthly family yield, the sum of the monthly income of all jobs from all family members was considered, excluding those family members who are pensioners, domestic workers or related to a domestic worker.

where the variable P_{it} is the poverty index proportion, $\inf_{it}$ is the infrastructure index, pib_{it} is the state GDP per capita, aem_{it} is the average years of schooling for people aged 25 or over, $gini_{it}$ is the Gini index, $regov_{it}$ are the state governments budget revenues, des_{it} is the unemployment rate, η_i represents non-observable unit effects, ε_{it} are random disturbances and i and t represent transversal and temporal observation indexes (states).

The hypothesis adopted in this model is: $E[\eta_i] = E[\varepsilon_{it}] = E[\eta_i \varepsilon_{it}] = 0$ e $E[\varepsilon_{it}\varepsilon_{is}] = 0$ for $i = 1,2,\ldots,N$ e $\forall t \neq s$. Additionally, there is a standard hypothesis related to the initial conditions: $E[P_{k,i0}\varepsilon_{it}] = 0$ for i = 1,2,...,N e t = 1,2,...,T (Ahn and Schimdt, 1995).

Traditional estimation techniques are inadequate for Eq. (1) due to two main econometric problems. The first one is the presence of non-observational effects in the η_i units and the second is the endogeneity of the explanatory variable P_{it-1} (one-period lagged dependent variable).[3] In this case, omitting fixed individual effects in the dynamic model panel makes ordinary least square (OLS) estimators tendentious and inconsistent. For example, due to a possible positive correlation between the lagged dependant variable and the fixed effects, the coefficient estimation β_1 is upward biased (Hsiao, 2004).

On the other hand, the fixed effect estimator, which corrects for the presence of heterogeneity in transversal units, generates and estimation of downward-biased β_1 in panels with a small temporal dimension. Studies developed by Monte Carlo, Judson and Owen (1999) showed that this bias can reach 20%, even in panels where $T = 30$. The second problem is due to the provable endogeneity of explanatory variables. In this case, an endogeneity on the right side of Eq. (1) must be treated to avoid a possible bias generated by a simultaneity problem.

Seeking to correct these problems, Arellano and Bond (1991) proposed the estimator for the Generalized Differentiated method of Moments (GMM). Such method consists of eliminating fixed effects through the first difference in Eq. (1), that is:

$$\Delta P_{it} = \beta_1 \Delta P_{it-1} + \beta_2 \Delta \inf_{it} + \beta_3 \Delta pib_{it} + \beta_4 \Delta aem_{it} + \beta_5 \Delta gini_{it} + \beta_6 \Delta regov_{it} + \beta_7 \Delta txdes_{it} + \Delta \varepsilon_{it} \quad (2)$$

where for a variable Z_{it} any, $\Delta Z_{it} = Z_{it} - Z_{it-1}$. By the construction of Eq. (2), ΔP_{it-1} and $\Delta \varepsilon_{it}$ are correlated and therefore, OLS estimators for their coefficients shall also be tendentious and inconsistent. In this case, it is necessary to employ instrumental variables for ΔP_{it-1}. The set of hypothesis adopted in Eq. (1) imply that the conditions in moments $E[\Delta P_{it-s}\Delta \varepsilon_{it}] = 0$, for $t = 3.4,\ldots T$ and $s \geq 2$, are valid. Based on these moments, Arellano and Bond (1991) suggest to use $P_{k,it-s}$, for $t = 3.4,\ldots T$ e $s \geq 2$, as equation instruments (2).

With regards to other explanatory variables, there are three possible situations. An explanatory Z_{it} may be qualified as (i) strictly exogenous, if not correlated to the terms of past, present and future errors; (ii) frankly exogenous, if it is only correlated to past error term values and; (iii) endogenous, if correlated with past, present and future error terms. In the second case, Z_{it} lagged values in one or more periods are valid instruments to estimate equation parameters (2). As for the last case, Z_{it} lagged values for two or more periods are valid instruments for Eq. (2).

Meanwhile, Arellano and Bover (1995) and Blundell and Bond (1998) argue that these instruments are weak when the dependant and explanatory variables have a strong persistence and/or the relative variance of fixed effects increases. This produces a non-consistent biased GMM estimator for panels with a small temporal dimension. Arellano and Bover (1995) and Blundell and Bond (1998) suggest a system that combines a set of equations in difference as a way to reduce the bias and imprecision problems (Eq. (2)) with a set of leveled Eq. (1). That is where the generalized moments system comes from. For difference equations, the set of instruments is the same described above. For the level regression, the most adequate instruments are the lagged differences of the respective variables.

For example, assuming that explanatory variable differences are not correlated to the fixed individual effects (for $t = 3.4,\ldots T$) and $E[\Delta P_{i2}\eta_i] = 0$, for $i = 1,2,3,\ldots,N$, then the different explanatory variables, either exogenous or frankly exogenous, and ΔP_{it-1}, are valid instruments for level equations. The same happens to the ΔP_{it-1} explanatory variables in lagged differences for a given period if they are endogenous.

The consistence of the GMM system estimator depends on the supposition of the absence of serial correlation in the error term and the validity of additional instruments. Consequently, at first, hypothesis with no correlation absence

[3] The variable P_{it-1} is endogenous to the fixed effect η_i in Eq. (1), originating a bias in the dynamic panel. Consider a state that experiences a very intense negative poverty shock for some non-modeled reason in a given year. All kept constant; the apparent fixed effect throughout the entire sampling period shall be bigger. Therefore, in the next period, the fixed effect and the lagged poverty of any particular period shall also be higher. This positive correlation between this regressor and η_i violates the hypothesis of consistence in the OLS estimation.

of first and second residual order are tested. Seeking to check that parameter estimators are consistent, the lack of first order autocorrelation hypothesis must be rejected and the second order autocorrelation is accepted. Later on, the Hansen test is performed to verify the validity of instruments used and the Sargan test is also carried out to check the validity of the additional instruments required by the GMM system method.

Results are introduced in the following section and variances estimators for parameters are robust with regards to the heteroscedasticity and the autocorrelation obtained through the GMM system. The estimator obtained is corrected through the Windmeijer's method (2005) to avoid that the respective variance estimators underestimate the real variances in a finite sampling.

5.1. Granger causality test for panel data

The concept of causality refers to the capacity of a variable to help in the behavior forecast of another variable of interest. It is about the existence of temporal anteriority in the explanation of a determined variable. One advantage of non-causality tests is related to the fact that in theory, they are immune to the problem of endogeneity (or simultaneity bias) as only lagged values of endogenous variables appear on the right side of the equations.

According to Granger (1969), in a bi-variable structure, the first variable is said to cause the second variable in the Granger sense if the forecast for the second variable improves when lagged values from the first one are considered. In this article we use the Granger causality procedure for panel data as supported by Hurlin and Venet (2004) and Hurlin (2004, 2005). This technique is therefore utilized to perform a specific causality existence test, as well as to detect the direction of any causality among variables, being consistent with the standard Granger causality where variables within the system need to be stable over time.

The causality test proposed by Hurlin and Venet (2004) and Hurlin (2004, 2005) applies to heterogeneous panel data with fixed effects. Initially, consider the following autoregressive model with T periods and N cross-section units:

$$Y_{it} = \alpha_i + \sum_{k=1}^{K} \gamma_i^{(k)} Y_{i,t-k} + \sum_{k=1}^{K} \beta_i^{(k)} X_{i,t-k} + \varepsilon_{i,t}$$

where K is the number of lags and $\gamma_i^{(k)}$ and $\beta_i^{(k)}$ are the coefficients of $Y_{i,t-k}$ and $X_{i,t-k}$ to be estimated, $i = 1.2,\ldots N$ and $t = 1.2,\ldots .T$.

It is assumed that individual effects α_i are fixed and K lags are equal for all units. As for the autoregressive parameters $\gamma_i^{(k)}$ and inclination regression coefficients $\beta_i^{(k)}$, they differ among individual units, however, these fixed parameters in time are considered.

This test has a null hypothesis H_0, the homogeneous non-causality (HNC) from the variable X to the variable Y, which means that there is no causal relation for all state panels. The alternative hypothesis H_1 considers the existence of a causal relation or a heterogeneous non-causality (HENC), from X to Y, for at least one cross-section unit.

Therefore, the test for the Homogeneous Non-Causality (HNC) shall be given by $H_0{:}\beta_i = 0, \forall i = 1, \ldots N$ against the alternative hypothesis of Heterogeneous Non-Causality (HENC) $H_1{:}\beta_i \neq 0\ \forall i = N_1 + 1, N_1 + 2, \ldots, N$, where N_1 is an unknown value, however it satisfies the condition that $0 \leq N_1/N < 1$.

This test considers the mean of the individual *Wald* test of non-causality between *N cross-sections.* The individual Wald statistic associated to the null hypothesis of Homogeneous Non- Causality is given by:

$$W_{N,T}^{HNC} = \frac{1}{N} \sum_{i=1}^{N} W_{i,T}$$

where $W_{i,T}$ represents the individual Wald test for the unit i. Based on the hypothesis of Non-Causality, we have that each of the individual Wald statistics asymptotically converges to a chi-square distribution with K degrees of freedom. On the other hand, the mean cross section $W_{N,T}^{HNC}$ converges to a normal distribution when T and N tend to be infinite.

The standardized statistic of $W_{N,T}^{HNC}$ may be obtained as follows:

$$Z_{N,T}^{HNC} = \sqrt{\frac{N}{2K}} \left(W_{N,T}^{HNC} - K \right) \underset{T,N \to \infty}{\overset{d}{\rightarrow}} N(0, 1)$$

where $T, N \rightarrow \infty$ represents the fact that $T \rightarrow \infty$ first and then $N \rightarrow \infty$.

For some temporal dimension, when T is fixed, the convergence of $W_{i,T}$ may not be reached. This means that although the Wald statistics may possess the same second order moments, they may not have the same distribution. Taking this into account, Hurlin and Venet (2004) and Hurlin (2004, 2005) proposed and approximation of the two first unknown distribution moments of $W_{i,T}$ with the two Fisher distribution moments. With this approximation and considering $T > 5 + 2K$, a semi-asymptotic statistic may be defined through the following expression:

$$\tilde{Z}_{N,T}^{HNC} = \sqrt{\frac{N}{2K} \times \frac{(T-2K-5)}{(T-K-3)}} \times \left[\frac{(T-2K-3)}{(T-2K-1)} W_{N,T}^{HNC} - K\right] \underset{N \rightarrow \infty}{\overset{d}{\rightarrow}} N(0, 1)$$

6. Results

The estimated results of the parameters obtained from Eq. (1) with the aid of Eq. (2) were obtained through the econometric techniques introduced in Section 5 and are now entered in Table A1.

In the model estimated through the GMM-S, explanatory variables considered endogenous were the dependent one-period lagged variable (P_{it-1}) and the per capita *GDP* (pib_{it}). The variables $\inf_{it}$ and $gini_{it}$ were treated as frankly exogenous and the others were considered as being strictly exogenous.

Initially, it was verified that the value of the coefficient estimation of β_1 for P_{it-1} through the GMM method (column [c]) was bigger than the one obtained through the EF (column [B] and smaller than the one obtained through MQO (Column [a]). As discussed in Section 5, MQO and EF estimations for β_1 are upward and downward biased respectively, providing approximate superior and inferior limits to guide the β_1 estimation through the GMM-S.[4] In this sense, the estimation bias of β_1 seems to have been minimized.

The tests performed through the GMM model reveal that the model statistical properties have been respected. The Hansen and Sargan tests, which check if instruments used and additional instruments required by the GMM system are valid, are satisfied. Finally, we also include the Arellano and Bond (1991) statistical tests to evaluate the existence of first and second order autocorrelation. Note that the absence of second order autocorrelation is essential for the consistence of the GMM-system estimator. The test confirms the non-rejection of first order autocorrelation although the second order autocorrelation hypothesis is indeed rejected.

The positive and significant positive estimated coefficient achieved through the GMM related to the lagged poverty index ($P_{0,it-1}$, column [c]) suggests that poverty is a dynamic and persistence process, once the response capacity of poverty in the current period with regards to past values is high, thus confirming the hypothesis of its persistence (vicious circle).

The remarkable result is the statistical significance of the effect of infrastructure on the measurement of the analyzed poverty. We observe that even through inadequate estimation methods (MQO and EF), the coefficient of this variable is statistically significant and presents the expected signs. This suggests that investments in infrastructure directly affect the temporal trajectory of poverty in Brazil, implying that there is a poverty reversion. This empirical evidence validates the idea that infrastructure has been fundamental for poverty reduction, being consistent with results found in the specialized literature as discussed in Section 3.

Somehow, these results corroborate those of Bertussi and Ellery (2012) as they studied the relation between public spending and economic growth in Brazil from 1986 to 2007. These authors concluded that public investment in the transport sector provokes a positive effect on the economic performance of Brazilian states and contributes to an income inequality reduction among them. In agreement with these findings, Ferreira and Malliagros (1998) and Mussolini and Teles (2010) highlight that important long-term relation between infrastructure and economic growth in Brazil.

This pro-poor impact in the Brazilian context may be assigned to several factors, as the proxy applied for the infrastructure variable is an index composed of four types of public expenses per capita: transportation, energy and mineral resources, communications and health and sanitation. Electricity reflects the access to technology and directly contributes to the improvement of employment levels and income for the poorest through economic growth. Investors tend to locate their businesses in areas that have services based on efficient technology, information and communications.

[4] This procedure is known as the *bounding procedure*. For a more detailed discussion on this, see Bond et al. (2001).

The expansion of these services in a country as a whole may strengthen the investment and corporate atmosphere, thus improving the general state of the economy and creating a positive environment for the low-income population.

The provision of drinking water and adequate sanitation services can help increase the aggregated economic growth, which translates into more jobs and better salaries for the poor. This grants that the poor can have access to drinking water sources and adequate sanitation services that improve health conditions, thus reducing job absenteeism and increasing income.

Among the other determinants, the per capita GDP and the average years of schooling also provided their respective estimated coefficients within expected results and were statistically significant. All these factors have contributed to poverty reduction. Such empirical evidences are confirmed by national and international economy literature, as detailed in Section 3.

The unemployment rate also presented a significant positive correlation with the poverty index. In the end, the higher the unemployment rate, the higher the percentage of poor people. This shows that including the unemployment rate in the model for business cycles and macroeconomic policies control purposes was a good idea.

The positive and significant coefficient of the Gini index suggests that income inequality in Brazil strongly contributes to the growth of poverty levels. This result corroborates those found in international articles such as Kalwij and Verschoor (2004) and Bourguignon (2004) as well as studies by Marinho and Soares (2003), and Hoffmann (2006) and Santos (2008) for Brazil. Besides, the estimated value of the coefficient for this variable is much higher than the GDP per capita. Therefore, policies aimed at inequality reduction are more effective to fight poverty than those aimed solely at boosting economic growth.

As for the state budget revenues, they offered results according to our expectations. Results reveal a negative relation between this variable and poverty, which ratifies conclusions reached by Seetanah et al. (2009) for a sample of 20 developing countries including Brazil. In fact, in recent years, more government funds has been used to reassign income to the poorest through income transfer programs.

These results prove that policies that encourage infrastructure investment and foster growth, income distribution and education are important to fight poverty intensity. However, if infrastructure, GDP growth and education policies increase income concentration, they may result in only moderate results or even worsen poverty.

The causality test results among model variables, according to Hurlin and Venet (2004) and Hurlin (2004, 2005) are introduced in Table A2.

It is observed that with three lags, p-values of statistics $Z_{N,T}^{HNC}$ and $\tilde{Z}_{N,T}^{HNC}$ allow us to conclude that the infrastructure index causes the poverty variable in the Granger sense. Likewise, since the correlation between poverty and infrastructure is negative, we can confirm that the expenses in infrastructure help reduce poverty. In the case of one or two lags only, the statistic $Z_{N,T}^{HNC}$ is significant.

Another interesting result verified is the reverse cause of poverty in the direction of the infrastructure index, which might be explained by the fact that more poverty may imply less infrastructure expenses. This empirical evidence confirms the results obtained by Rajkumar and Swaroop (2008) and Seetanah et al. (2009) as described in Section 2.

With regards to other poverty determinants, we could verify through the p-values of statistics $Z_{N,T}^{HNC}$ and $\tilde{Z}_{N,T}^{HNC}$ that there is also a reverse causality of poverty against all of them, thus validating such determinants.

Finally, since poverty causes a negative impact on the per capita GDP in the Granger sense, it suggests the existence of a vicious circle.

7. Conclusions

Results obtained from econometric models suggest that poverty is a dynamic and persistent process, as its response capacity in the current days is high in comparison to the past, thus confirming the hypothesis of a vicious circle.

The most remarkable result is the effect that infrastructure exerts on poverty reduction. This means that investments in infrastructure directly affect its temporal trajectory in Brazil, in the sense that there is a reversion of this situation. Such empirical evidence validates the idea that infrastructure has been fundamental for poverty reduction. This pro-poor people impact in the Brazilian context may be assigned to several factors, as the proxy used to measure infrastructure is an index composed of four different types of public expenses per capita: transports, energy and mineral resources, communications and health and sanitation.

With regards to the other analyzed determinants, the per capita GDP and the average schooling years have also contributed to diminished poverty levels. It is worth highlighting that such empirical evidences confirm results found in the national and international literature.

The unemployment rate also showed a significant positive correlation in comparison to the poverty index. In the end, the higher the unemployment rate, the higher the proportion of poor people. Since this variable is affected by business cycles and macroeconomic policies, the government should be concerned about implementing measures that can stabilize the economy. Although income inequality has been reduced in recent years, it still contributes strongly to the poverty growth. This result confirms findings from national and international papers. Besides, the impact of this variable on poverty is much higher than the per capita GDP. Therefore, policies aimed at the reduction of inequalities are more efficient to fight poverty than those solely focused on economic growth.

As for the state budgets, we noticed a negative correlation of poverty with regards to the poverty index, which ratifies results obtained by Seetanah et al. (2009) for a sample of 20 developing countries including Brazil. In fact, in recent years, more government funds have been used to reassign income to the poorest through income transfer programs.

Another interesting result is the reverse causation of poverty in the direction of the infrastructure index, which may be explained by the fact that higher poverty levels may imply less infrastructure expenses. This empirical evidence corroborates results obtained by Rajkumar and Swaroop (2008) and Seetanah et al. (2009). Additionally, since poverty causes a negative per capita GDP impact in the Granger sense, we can conclude that there is indeed a poverty vicious cycle. This vicious cycle is aggravated due to the intense persistence of poverty.

Summarizing, results obtained show that policies aimed at encouraging infrastructure investment, as well as sustainable growth, income distribution and education are important to fight poverty intensity. However, if infrastructure investment, GDP growth and education policies increase income inequality, they may result in only modest results or even worsen poverty.

Appendix A.

Table A1
Estimations and statistics of model 2 parameters.

	MQO [a]		Fixed effects [b]		GMM—system [c]	
	Coefic.	Value-p	Coefic.	Value-p	Coefic.	Value-p
$P_{0,it-1}$	0.9393 (0.0139)	0.000	0.5567 (0.0339)	0.000	0.5952* (0.0772)	0.000
$\inf_{it}$	−3.13E − 05 (8.74E − 06)	0.000	−4.70 E − 05 (9.06E − 06)	0.000	−2.5E − 05* (1.25E − 05)	0.056
pib_{it}	−3.45E − 07 (8.57E − 07)	0.687	8.67E − 07 (1.39E − 06)	0.533	−7.8E − 06* (2.85E − 06)	0.011
aem_{it}	−0.0046 (0.0028)	0.103	−0,0260 (0.0030)	0.000	−0.0078** (0.0043)	0.082
$gini_{it}$	0.1335 (0.0584)	0.023	0.3723 (0.0728)	0.000	0.7202* (0.2204)	0.003
$regov_{it}$	2.23E − 09 (1.94E − 08)	0.909	−7.78E − 08 (1.73E − 08)	0.000	−4.64E − 08* (1.96E − 08)	0,026
des_{it}	0.0026 (0.0007)	0.000	0.0006 (0.0011)	0.575	0.0042** (0.0024)	0.090
Const.	−0.0386 (0.0399)	0.334	0.1455 (0.0521)	0.000	−0.1540 (0.1130)	0.185
$F(7.370) = 1331.31$			$F(7, 344) = 296.31$		$F(7. 26) = 99.18$	
Prob > F = 0.0000			Prob > F = 0.000		Prob > F = 0.000	
$R^2 = 0.96$						
N° of obs: 378			N° of obs: 378		N° of obs: 378	
			N° of groups: 27		N° of groups: 27	
					N° of instruments: 20	
H_0: absence of first order residual autocorrelation			Value-p		0.01	
H_0: absence of second order residual autocorrelation			Value-p		0.98	
Hansen test			Prob > chi^2		0.29	
Sargan test			Prob > chi^2		0.32	

Source: Results obtained by the author through the Software Stata 11.0.
Notes: (i) Values between parentheses are standard deviations corrected through the Windmeijer (2005) method.
(ii) Values for the Hansen test are the p-values for the null hypothesis that instruments are valid. This test is not robust but its performance is not affected by the presence of several instruments.
(iii) Values for the Sargan test are the p-values for the validity of additional instruments required by the system method. This is a robust test but its performance is affected by the presence of several instruments.
(iv) Values contained in lines AR(1) and AR(2) are the p-values for first and second order autocorrelations of first difference equation errors.
(v) * significance at the level of 5%, ** significance at the level of 10%.

Table A2
Causality test for the model.

Lags	K = 1		K = 2		K = 3	
Tests statistics	$Z_{N,T}^{HNC}$	$\tilde{Z}_{N,T}^{HNC}$	$Z_{N,T}^{HNC}$	$\tilde{Z}_{N,T}^{HNC}$	$Z_{N,T}^{HNC}$	$\tilde{Z}_{N,T}^{HNC}$
$P_{it} \rightarrow \text{inf}_{it}$	13.0 (0,000)	8.7 (0.000)	27.8 (0.000)	7.8 (0.000)	35.2 (0.000)	4.8 (0.000)
$\text{inf}_{it} \rightarrow P_{it}$	2.1 (0,033)	1.0 (0.319)	6.0 (0.000)	1.0 (0.296)	28,5 (0,000)	3.7 (0,000)
$P_{it} \rightarrow Pib_{it}$	3.8 (0.000)	2.1 (0.037)	12.1 (0.000)	2.9 (0.003)	20.3 (0,000)	2.3 (0.020)
$Pib_{it} \rightarrow P_{it}$	9.0 (0.000)	5.9 (0.000)	16.0 (0.000)	4.2 (0.000)	88.6 (0.000)	13.7 (0.000)
$P_{it} \rightarrow aem_{it}$	6.0 (0.000)	3.8 (0.000)	23.9 (0.000)	6.4 (0.000)	119.4 (0.000)	18.84 (0.000)
$aem_{it} \rightarrow P_{it}$	6.5 (0.000)	4.1 (0.000)	13.3 (0.000)	3.3 (0.001)	49 (0,000)	7.3 (0.000)
$P_{it} \rightarrow gini_{it}$	7.4 (0.000)	4.77 (0.000)	16.3 (0.000)	4.2 (0.000)	28.3 (0.000)	3.7 (0.000)
$gini_{it} \rightarrow P_{it}$	8.2 (0.000)	5.3 (0.000)	34.4 (0.000)	9.9 (0.000)	92.7 (0,000)	14.4 (0.000)
$P_{it} \rightarrow regov_{it}$	0.9 (0.379)	0.11 (0.915)	65.0 (0,000)	19.4 (0.000)	16.4 (0,000)	1.7 (0.093)
$regov_{it} \rightarrow P_{it}$	1.3 (0.21)	0.4 (0.707)	1.8 (0.074)	−0.3 (0.80)	37.2 (0,000)	5.1 (0.000)
$P_{it} \rightarrow des_{it}$	1.9 (0.062)	0.8 (0.421)	35.6 (0.000)	10.2 (0.000)	103.4 (0.000)	16.2 (0,000)
$des_{it} \rightarrow P_{it}$	−0.9 (0.393)	−1.13 (0.259)	6.5 (0.000)	1.2 (0.227)	84.5 (0.000)	13.03 (0.000)

Source: Results obtained by the authors through Software MATLAB 7.9.
Notes: Values in parenthesis are p values. The symbol → points at the Granger causality direction.

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