Infrastructure and income inequality: an application to the Brazilian case using hierarchical spatial autoregressive models

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ABSTRACT

Many scholars have highlighted the role of infrastructure in reducing income inequality. Developing economies present immense regional and income discrepancies, which are correlated with unequally distributed infrastructure in territorial and population terms. In this paper, we assess the effects of infrastructure supply on income inequality and verify whether these effects vary according to the infrastructure sector and its degree of quality and access in a particular state or municipality in Brazil. The analysis is based on spatial hierarchical models. Results allow us to say that infrastructure correlates negatively with income inequality, as well as reinforces the importance of considering heterogeneities between sectors and specific characteristics of infrastructure. Hence, public infrastructure policies aimed at improving infrastructure quality and, essentially, expanding access are crucial for achieving lower levels of income concentration.

Keywords: infrastructure, income inequality, Brazil, spatial econometrics, multilevel approach.

RESUMO

O papel da infraestrutura sobre a desigualdade de renda tem sido destacado por muitos estudiosos. O caso brasileiro apresenta imensas discrepâncias regionais e de renda, as quais contribuem para uma infraestrutura desigualmente distribuída em termos territoriais e populacionais. Uma análise hierárquica e espacial é realizada. Os resultados da pesquisa permitem dizer que a infraestrutura se correlaciona negativamente com a desigualdade de renda, bem como reforçam a importância de se considerar heterogeneidades entre setores e características da infraestrutura. As estimações apontam para heterogeneidades e dependências espaciais na medida de desigualdade, indicando uma boa adequação da abordagem proposta à realidade brasileira.

Palavras-chave: infraestrutura, desigualdade de renda, Brasil, econometria espacial, abordagem mulltinível.

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1. INTRODUCTION

In a context of strong fiscal adjustment, economic stagnation and rising income inequality in many developing countries, many economists have pointed to investment in infrastructure as a key variable that can foster economic growth with a reduction in poverty and social inclusion (Ali & Pernia, 2003; Calderón & Servén, 2014). Previous studies have proven the importance of infrastructure as a promoter of economic growth through increasing productivity of production factors, improvements in competitiveness and trade, as well as its complementary effects in the formation of higher levels of private investment (Aschauer 1989, 2004; Calderón, Moral-Benito & Servén, 2014; Munnell, 1992). Nevertheless, the possible channels of transmission of infrastructure on income inequality are unclear.

From a theoretical perspective, an adequate infrastructure provides several positive social impacts that include, in addition to improving environmental conditions and energy use, better education and health conditions, access to public goods and services, equality and social inclusion. Finally, infrastructure is seen as a tool for structural change in the economy since it unites transversal advances in economic, environmental and social terms, generating a process of sustained economic and inclusive growth, thus benefiting the poorest part of the population (Sanchez et al., 2017; United Nations, 2016).

Empirical studies about that theme, however, are still very scarce, with substantial differences found in the main results. While some conclusions point to a positive or null relationship between infrastructure and income inequality (Bajar & Rajeev, 2015; Makmuri, 2017; Mendoza, 2017), other researches indicate that infrastructure expansion is a key factor in reducing inequalities (Calderón & Chong, 2004; Calderón & Servén, 2004, 2010; Hooper et al., 2017; Makmuri, 2017; Raychaudhuri & De, 2010; Seneviratne & Sun, 2013). In addition to the scarcity of studies, many limitations can be noted in the existing literature. A first point concerns the variables used. Few studies take into account different aspects of infrastructure, such as supply, quality and access. Infrastructure supply indicators alone may say little about the impacts of infrastructure on issues such as inequality and poverty, since the expansion of these assets can be concentrated on richer and urbanized regions, not necessarily translating into greater supply for the poorest. Another issue that is not explicitly addressed in the literature on infrastructure and inequality concerns spatial issues. Theoretically speaking, infrastructure affects the choices of both firms and families, and since it is distributed asymmetrically between regions, it decisively influences agents' localization decisions such as migration, establishment of new companies, capital investment in different locations etc. (Ottaviano, 2008). Empirical studies on infrastructure and economic growth have proven the existence of such proximity spatial interactions (Arbués et al., 2015; Cosci & Mirra, 2017; Del Bo & Florio, 2008, 2012); however, although it is likely, it is unknown whether the same pattern of interaction can be observed for inequality.

The Brazilian case presents interesting peculiarities. We observe a setback of a long cycle of falling income inequality, which began at the end of the 1990s. In 2015, the country shows the first high in the Gini Index since the turn of the century. In addition to the worsening of inequality indicators, there is a sharp drop in infrastructure investment, which was around 1.5% of GDP in 2017 (ABDID, 2018), one of the lowest levels of infrastructure investment in the country history. While these investments exceeded 6% of GDP in the 1970s, the current ratio does not even cover the infrastructure losses that occur through depreciation. Decades of insufficient investment has contributed to a precarious current infrastructure in several aspects, which include insufficient supply, poor quality and limited population access in most sectors.

Another intriguing specificity of the Brazilian economy refers to the immense regional and income discrepancies. In relation to the regional contrasts, there are large regional heterogeneities in general represented by an extremely poor and unequal North–Northeast region and a richer and more egalitarian Center–South region. Similarly, one can observe strong spatial autocorrelation patterns in the incidence of inequality in Brazilian states and municipalities (Silva & Leite, 2017), since more unequal municipalities perpetuate similar conditions in terms of poor infrastructure, low educational level, limited governmental technical capacity, poor quality of health etc., propagating a vicious cycle of transmission of these inequalities to their neighbors. The distinctions of income are also remarkable. In 2015, about 85% of the richer population was served with Internet service, while only 21% of the poorer population was covered by this same service. A similar situation is observed with regard to sewage, and there is still a considerable parcel of the poor population who are without access to treated water (Raiser et al., 2017).

In a context that includes immense spatial heterogeneities, as in the Brazilian case, are there any effects of infrastructure supply on income inequality? Do these effects vary according to the infrastructure sector and its degree of quality and access in a particular state or municipality? In order to answer these questions, a broad database of varied indicators for the transportation, power, telecommunications and sanitation sectors is elaborated. This paper tests, for the first time, many of these indicators. The inclusion of several sectoral infrastructure measures, which include supply, quality and access in the sectors analyzed, allow a more realistic and specific analysis of the effects of these sectors on income inequality. In this way, the existence of heterogeneous effects of the infrastructure itself can be verified. Another contribution of this study concerns the inclusion of spatial aspects in the econometric model. In this sense, the use of hierarchical and spatial models is proposed, which allows us to treat both spatial heterogeneity (data distributed at different levels, such as municipalities and states) and spatial autocorrelation (spatial proximity interactions). This is, to the best of our knowledge, the first study that empirically investigates the relationship between infrastructure and income inequality, taking into account spatial dependencies and heterogeneities, as well as infrastructure effects heterogeneities.

The paper is organized as follows. The next section presents the variables used in the study as well as their respective sources and treatment methods. The third section describes the methodologies utilized. The estimated results of infrastructure effects on income inequality, taking into account both spatial heterogeneity and spatial dependence through spatial hierarchical models, are reported in the fourth section. Finally, the conclusions of the work are made.

2. DATABASE AND INFRASTRUCTURE MEASUREMENT STRATEGY

Due to data limitations, the representative variables of supply and quality of the transport, energy and telephony sectors will be arranged in state aggregations. Toward the categories of sanitation and Internet and the access indicators representing electricity and telephony services, the aggregation is taken in municipal character. As it is possible that infrastructure investments take some time to mature and generate effects on economic development (Hooper et al., 2017; Makmuri, 2017), we sought to include previous years together with the year 2010. However, another limitation arising from the unavailability of data is related to the time at which data on infrastructure is available, period that varies according to the sector analyzed. To mitigate possible problems of discrepant observations or null values for some years, averages were calculated for the supply and quality variables for the period 2004–2010. Exceptions are given in the case of telecommunications, where data are available for the 2007–2010 period, and for infrastructure access variables, which, in turn, are for the year 2010. The data sample contains 5,426 observations.

In this way, the infrastructure variables were created following the national and international literature, considering the different sectors that make up the concept of infrastructure (Bajar & Rajeev, 2015; Calderón & Chong, 2004; Calderón & Servén, 2004, 2010; Chakamera & Alagidede, 2017; Makmuri, 2017; Straub & Hagiwara, 2010). Variables to represent the sectors of transportation, power, telecommunications and basic sanitation are captured. Then, the variables disaggregated by sectors are used to generate new measures in order to better describe the multidimensional aspect of infrastructure (Calderón & Servén, 2014). Therefore, indexes representing infrastructure supply, quality and access are created through Principal Component Analysis (PCA), which each one includes—whenever it is available—variables from all infrastructure sectors analyzed in this work.

Finally, we used the variables of supply, quality and access to create "hybrid" indexes of infrastructure, analyzed by sector and in aggregate form. It is assumed that quality can act as a burden that enhances (or limits) the effects of infrastructure supply on income inequality (Chakamera & Alagidede, 2017). Similarly, it is argued that access to infrastructure may weigh the relationship between infrastructure supply and income inequality, whereas this infrastructure can be allocated asymmetrically in the population. In this way, indices for the various sectors were created as the interaction of the supply variables with those of quality and access.

2.1 Infrastructure supply

The first group of representative infrastructure variables is related to their supply level. This type of variable captures the provision of a given infrastructure sector for a given state or municipality. In other words, it concerns the stock of power, transportation, telecommunications and sanitation that is offered for general use by the population.

In relation to the transportation sector, the natural logarithm of the total extension of paved and unpaved roads (km) divided by the state population is used as a proxy variable. To represent the power sector, the indicator residential energy consumption (GwH) *per capita* is used. Regarding telecommunication sector, two quantity variables are used. The first one represents Internet supply, being arranged by the natural logarithm of Internet accesses divided by the number of inhabitants of each municipality. The second measure consists in the natural logarithm of the sum of fixed and mobile telephony accesses divided by the number of state inhabitants. Municipal sanitation quantity is represented by the logarithm of the treated water volume distributed per day (m^3) *per capita*, which is collected from the National Survey of Basic Sanitation for the year 2008 (IBGE, 2008).

2.2 Infrastructure quality

The second group of infrastructure variables seeks to capture the quality of the sectors, or their efficiency. In this sense, these measures represent the capacity of a given infrastructure to effectively provide the expected services, such as the moving of people with safety and speed, water with adequate conditions for people's health etc. Given that none of the supply variables contain these characteristics, it is fundamental to include the indicators of infrastructure quality, since supply effects can be heterogeneous according to their efficiency (Calderón & Servén, 2010, 2014; Makmuri, 2017; Straub, 2011).

The transportation quality is represented by the percentage of total length of highways (km) classified as being in good and excellent condition. It is believed that the variable chosen in this study is adequate because, besides taking into account the paving of highways, it considers other qualitative issues related to road safety and conservation (CNT, 2018).

Regarding power quality, the natural logarithm of the ANEEL (National Electric Energy Agency) Consumer Satisfaction Index (IASC) will be used. This index allows evaluating the residential consumer satisfaction with the services rendered by the electric power distributors, capturing items such as: perceived quality; perceived value (cost-benefit ratio); overall satisfaction; confidence in the supplier; and fidelity. For those states that were served by more than one electric power distributor, simple arithmetic averages of distributors were calculated.

In relation to the telecommunication sector, two variables are used to capture Internet and telephony quality. The first one refers to the proportion of Internet accesses with speed above 512 Kbps, connection that are classified as non-slow speed. The choice of this variable followed the classification made by Swiss (2011). Telephony quality is represented by the Completed Originated Call Rate. In the telephony case, since the states are served by more than one provider, state averages of these rates were calculated.

To represent sanitation quality or, in this case, inefficiency, we use the proportion of hospitalizations from waterborne diseases. This variable captures qualitative aspects related to inefficiency in the treatment of water and sewage, with consequent implications on the number of hospitalizations due to diseases caused by sanitation quality.

2.3 Infrastructure access

The last range of variables used refers to that representing population access to infrastructure, all with municipal scope. Access, in the sense used in this work, is understood as the ability or the possibility that people have to utilize some infrastructure service.

In order to depict access to infrastructure, variables of the Demographic Census are collected. This survey allows us to evaluate household access to infrastructures. Then, household measures are aggregated at the municipal level. Regarding transportation sector, there are no available variables fulfilling the proposed requirements for this type of variable. Power access is represented by the percentage of households with electricity. Similarly, telecommunications access, reproduced here by telephone services, is represented by the percentage of households with access to fixed or mobile telephone. In turn, basic sanitation access is represented by the percentage of households with adequate water supply and sanitary sewage. Table C1 in Appendix C summarizes the infrastructure variables used.

2.4 Composite indices: an application of Principal Component Analysis (PCA)

The indexes are created by Principal Component Analysis according to infrastructure characteristic and its aggregation. Therefore, for the supply case two indices are calculated, one containing the state-level variables, and the other with the municipal level variables. The same is true for quality measures. In relation to access indicators, a single index is created in municipal aggregation. A full description of the method can be obtained in Dunteman (1989).

Table D1 in Appendix D describes the proportion of the variance and its accumulation with the different components for the indices created. In all cases, we chosen to use those components that had an eigenvalue greater than one, following the Kaiser's criterion (Kaiser, 1958). The indices are described in the equations below:

$$SIS = -0{,}283 * Otransp + 0{,}696 * Oenerg + 0{,}661 * Otelec2 \quad (1)$$
$$MIS = 0{,}707 * Osanea + 0{,}707 * Otelec1 \quad (2)$$
$$SIQ = 0{,}689 * Qtransp + 0{,}663 * Qenerg + 0{,}291 * Qtelec2 \quad (3)$$
$$MIQ = -0{,}707 * Qsanea + 0{,}707 * Qtelec1 \quad (4)$$
$$IAI = 0{,}503 * Asanea + 0{,}593 * Aenerg + 0{,}628 * Atelec \quad (5)$$

The first index created, named State Infrastructure Supply Index (SIS), condenses the information about power, telephony and transport state-level variables. According to equation 1, power and telephony indicators have a substantial weight in the index, with a positive sign. The second index, designed Municipal Infrastructure Supply Index (MIS), added information on sanitation and Internet provision indicators, which have the same positive weight in the composite index.

A similar procedure is implemented for quality measures, creating the State Infrastructure Quality Index (SIQ) and the Municipal Infrastructure Quality Index (MIQ), with the same sectors as the supply indexes. While in the municipal index the variables of sanitation inefficiency and Internet quality have the same weight, in the state index the variables that hold the highest weight are those linked to the transportation and power sectors.

Finally, the Infrastructure Access Index (IAI) synthesized information on the variables of access to electricity, telephony and sanitation. All variables had a significant influence on the index, in such a way that it represents well the access to infrastructure in the Brazilian municipalities. The composite indicators described in the equations above are used in the subsequent econometric analysis.

2.5 Hybrid indices: interactions between infrastructure characteristics

The hybrid indexes proposed in this paper seek to simultaneously capture the aggregate effects of access, quality and infrastructure supply indicators. When analyzing the links between infrastructure and income inequality, having only one supply indicator is insufficient. In addition, separate analysis of the effects of provision, access and quality, may not fully reveal the impact of the infrastructure, which is a great challenge in the causality test. Finally, no studies using a hybrid aggregate index that considers both the infrastructure stock and access were found, in such a way that it becomes a contribution of this study to test such interactions in the econometric models. Hybrid indices can be described as:

$$SSQ = SIS * SIQ \quad (6)$$

$$MSQ = MIS * MIQ \quad (7)$$

$$SSA = SIS * IAI \quad (8)$$

$$MSA = MIS * IAI \quad (9)$$

In equations 6 and 7 the interactive indices are described between supply and quality both at the state and municipal level, respectively. In relation to hybrid indicators of quantity and access, two indicators were also created, both state and municipal level (equations 8 and 9, respectively). This choice was chosen due to the fact that the telephony and power sector have municipal access indicators, however, their supply is arranged by state. On the other hand, sanitation access and provision are given at the municipal level, and an interaction at this level is necessary. The same procedure is done for the disaggregated variables. The multiplication between supply and quality is named with the initials S (supply) and Q (quality) (example SQtransp to the transportation sector), while the interaction between supply and access is named with the initials S and A (access) (example OAenerg to the power sector).

2.6 Income inequality and control variables

In order to represent income inequality, we use “Ratio 10/40 (r1040),” a measure that compares the average per capita household income of the individuals belonging to the richest decile of the distribution, with the average per capita household income of the individuals belonging to the poorer two-fifths of people. The universe of individuals is limited to those who live in permanent private households.

The control variables are represented by the logarithm of the industrial value added per capita, the logarithm of the aggregate value of agriculture per capita, the logarithm of the value added of the services sector per capita, logarithm of the education human development index, logarithm of health human development index, formalization degree of employed persons, rate of infant mortality and the logarithm of total population. All control variables, as well as the dependent variable, are from the year 2010. Table C2 in Appendix C summarizes this group of variables, while Table C3 describes the descriptive statistics of the variables used in the work.

3. INFRASTRUCTURE EFFECTS ON INCOME INEQUALITY IN A REGIONAL APPROACH: THE HIERARCHICAL SPATIAL AUTOREGRESSIVE MODEL (HSAR)

Since spatial heterogeneities and dependencies patterns can coexist, it is necessary to treat these two types of problem together. A model that solves such difficulties is the hierarchical spatial autoregressive model (HSAR), proposed by Dong and Harris (2014). According to the authors, the purposes of HSAR are: i) to avoid the "ecological fallacy," which occurs when transferring relations between variables on an aggregate scale for individuals; ii) to avoid the "atomistic fallacy," when correlations between variables are investigated exclusively at individual level, without taking into account the context; iii) investigate and quantify contextual effects; and iv) provide better estimates of model parameters and their standard errors in the presence of group effects.

The motivation of Dong and Harris (2014) in HSAR elaboration was linked to the inability of conventional hierarchical models to deal with spatial issues that went beyond group heterogeneity. According to the authors, classical hierarchical models would be able to treat the so-called "vertical group dependence" (or spatial heterogeneity at the macro level), which occurs when lower level units are similar, since they absorb identical group effects. However, such models fail to treat the so-called "horizontal group dependence" (or spatial autocorrelation), characterized by interactions and spillovers that occur due to geographic proximity.

The HSAR model, by including the hierarchical data, provides more efficient and accurate estimates for the regression coefficients. In addition, it provides more correct estimates of the intensity of spatial interaction at the lower level, separating it from the measurement of regional effects, with which it can be confused. In this sense, the HSAR model simultaneously integrates spatial autoregressive processes (SAR) for both the response variable and the upper level residues within a classical hierarchical approach. The key feature of the SAR process is that it allows the observed values of a dependent variable y in a particular locality to be directly dependent to the values observed in neighboring locations (or spatial lag of y), providing both specification and measurement of interaction effects (or spatial spillovers) (LeSage & Pace, 2009). HSAR model specification follows as:

$$y = \rho W y + X\beta + Z\gamma + \Delta\theta + \varepsilon \qquad (10)$$
$$\theta = \lambda M\theta + u$$
$$\Delta = \begin{bmatrix} l_1 & 0 & \cdots & 0 \\ 0 & l_2 & \dots & \vdots \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \cdots & l_j \end{bmatrix}$$

Where y is a column vector N × 1 of the dependent variable values; ρ is the level 1 spatial autoregressive parameter; W is the spatial weights matrix at municipal level; X is a matrix N × K of independent variables at the level one; β is a matrix K × 1 of regression coefficients at the municipal level; Z is an N × P matrix of level two variables; γ is the vector P × 1 of corresponding coefficients of level two; Δ is a diagonal block matrix N × J with column vectors of ones; and ε is a level one random error term, distributed as $N(0, \sigma_e^2)$.

The vector J × 1 of level two residues, $\theta[\theta_1, \theta_2, \dots, \theta_j]$, represents contextual random effects. The residuals u are distributed as $N(0, \sigma_u^2)$, and it is assumed that they are independent of ε. Similar to W, M is a normalized spatial weights matrix at level two, while the parameter λ measures the intensity of spatial interactions at state level. Finally, specified as a SAR process, the covariance matrix for θ is $cov(\theta) = \sigma_u^2(B'B)^{-1}$, where $B = I_J - \lambda M$. As a consequence, the distribution of θ is multivariate normal, $\theta \sim N(0, \sigma_u^2(B'B)^{-1})$.

The spatial multipliers ρ (Corrado & Fingleton, 2012) and λ indicate nothing more than that spatial dependence process can have causes such as: i) spatial externalities coming from explanatory variables; ii) spatial externalities coming from not observed factors; and iii) a feedback or diffusion effect on y; in other words, some unobserved spatial factor that is captured in the error term. Since there are spatial interaction effects, a variation in some independent variable in municipality i has a direct effect on municipality i and an indirect effect on other municipalities. The same is true for a variation in a state-level independent variable. The direct, indirect and total effects calculation methods can be seen in Dong and Harris (2014). HSAR model estimation is implemented through a Bayesian simulation approach using Markov Chain Monte Carlo (MCMC) algorithms.

4. RESULTS AND DISCUSSION

The first practical step is to test the existence of global spatial autocorrelation using Global Moran's I statistic. As described in Table E1 in Appendix E, we can reject the null hypothesis that there is no spatial autocorrelation in all the variables analyzed, except for transportation supply and telephony quality. However, the Moran's I statistic is purely global, thus not allowing us to determine possible clusters and spatial outliers between the municipalities. Local measurements of spatial autocorrelation are more adequate for this type of inference. Figure 1 graphically depicts Local Moran's I statistic for the income inequality measure. The map includes municipal values for the Moran Scatterplot that were statistically significant at the 5% level.

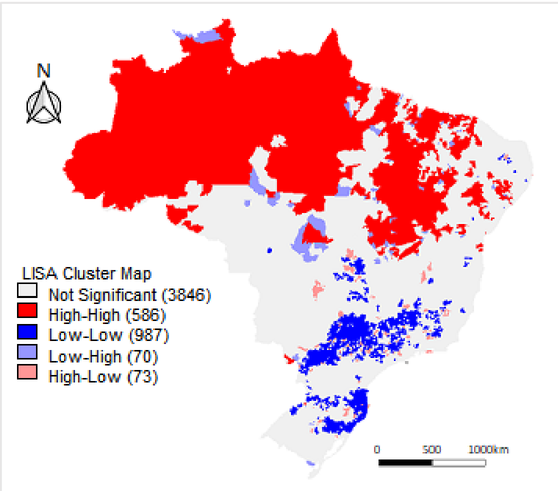

Figure 1 – Local Moran's I statistic for income inequality (r1040) in Brazil, 2010.

It can be seen from Figure 1 that there are clusters for income inequality. Without great details, Brazil can practically be divided into two. North and Northeast regions have large clusters that are negatively highlighted, that is, municipalities with high inequality values are surrounded by other municipalities also with a high-income concentration. South and Southeast regions, although to a lesser extent in relation to the North and Northeast, present sets of municipalities, in proximity, with low-income inequality.

Before proceeding with spatial model estimations, we estimate the null conventional hierarchical model in order to analyze the importance of including a second (state) hierarchical level in the analysis. The value of intraclasses correlation coefficient of 0.66 indicates the importance of modeling the variance between groups. In other words, about 66% of the variance of income inequality can be explained by the hierarchical structure of the data.

Since spatial exploratory analysis indicated remarkable spatial dependence patterns in the analyzed variables and the null conventional multilevel model indicated the presence of group dependence, the next step of the work is the application of the spatial hierarchical model. According to the HSAR model estimates set out in Appendix G, both spatial parameters, ρ and λ, are significant in all specifications, indicating the importance of considering neighborhood interactions at the lower (municipal) and upper (state) levels, respectively. Regarding the control variables, it can be observed that the formalization degree of workers, the level of educational and health human development, and industrial value added correlate negatively with income inequality. On the other hand, the larger the population of the municipality, the infant mortality rate and the value added in the service sector, the lower the personal income equality in the municipalities.

When we include the supply variables without any type of weighting (Table 1), it can be observed that only sanitation and telephony supply indicators correlate significantly with the municipal income inequality. The total effect of a 1% increase in the sanitation supply provides an income ratio of the richest 10% over the poorest 40% (r1040) 0.149 times lower. This total effect comes from: i) direct impacts of sanitation expansion in the municipality in which it is done, where a 1% increase in the basic sanitation provision correlates directly with a ratio (10/40) 0.105 times lower; and ii) a feedback mechanism that spreads to neighboring municipalities and returns to the municipality itself, generating a return in terms of lower levels of income inequality of approximately 0.044. Similarly, a 1% expansion in the telephony state-level stock correlates with a "10/40 ratio", on average, 6.93 times lower (with a direct impact of -4.878 and an indirect effect of -2,052).

Table 1 - Direct, indirect and total impacts of infrastructure supply on income inequality (ratio 10/40).

Variable/ Impact	Direct	Indirect	Total
	Posterior Mean	Posterior Mean	Posterior Mean
Ssanea	-0.105* (0.038)	-0.044* (0.016)	-0.149* (0.054)
Stransp	0.731 (0.817)	0.308 (0.344)	1.039 (1.16)
Senerg	1.035 (1.776)	0.437 (0.749)	1.472 (2.525)
Stelec2	-4.878* (1.727)	-2.052* (0.726)	-6.93* (2.453)
Stelec1	0.087 (0.125)	0.037 (0.053)	0.124 (0.178)
MIS	-0.264* (0.127)	-0.111* (0.054)	-0.375* (0.181)
SIS	-1.154 (0.74)	-0.485 (0.311)	-1.639 (1.052)

Notes: (*) indicates statistically significant parameter in a 95% Credible Interval (CI), standard errors in parentheses.

The Municipal Infrastructure Supply (MIS) Index also spreads significant effects on income concentration. The increase of 1% in the MIS negatively affects the income ratio by 0.375 units (-0.264 as direct impact and -0.111 via spatial interactions). Since MIS captures information on the Internet service and basic sanitation municipal supply, this result indicates that the expansion of these services is an important factor for municipalities to reach higher levels of income equality.

The results presented so far provide good evidence about infrastructure effects on inequality, which corroborate much of the related literature (Calderón & Chong, 2004; Calderón & Servén, 2004, 2010; Raychaudhuri & De, 2010) where negative effects of infrastructure supply on personal income inequality were found. However, a more careful analysis encompasses the study of various infrastructure characteristics, such as its quality and access. Next, the supply variables are weighted for their respective quality, in order to capture possible heterogeneities in supply infrastructure effects on income concentration.

Table 2 shows the total, direct and indirect infrastructure supply effects weighted by its quality. Since we have included interactive variables between supply and quality, we have the supply term involved in two regression parameters (for example, $r1040 = \beta_1 * Ssanea + \beta_2(Stransp * Qtransp)$). The marginal effect of an expansion in infrastructure supply can be obtained with the partial derivative $\frac{\partial r1040}{\partial Supply} = \beta_1 + \beta_2 * \overline{Quality}$, where $\overline{Quality}$ indicates the average value of a certain quality infrastructure indicator. The mean values used to calculate the marginal effects can be obtained in Table C3 in Appendix C.

Table 2 - Direct, indirect and total impacts of infrastructure supply and quality on income inequality (ratio 10/40).

Variable/ Impact	Direct	Indirect	Total
	Posterior Mean	**Posterior Mean**	**Posterior Mean**
Ssanea	-0.140* (0.042)	-0.059* (0.018)	-0.198* (0.06)
SIsanea	0.383* (0.179)	0.161* (0.075)	0.543* (0.254)
Stransp	0.60 (0.709)	0.254 (0.3)	0.854 (1.008)
SQtransp	-4.785* (2.635)	-2.024* (1.115)	-6.809* (3.749)
Senerg	33.312* (9.047)	14.087* (3.826)	47.399* (12.873)
SQenerg	-8.107* (2.231)	-3.428* (0.944)	-11.535* (3.175)
Stelec2	-2.39 (8.995)	-1.002 (3.77)	-3.392 (12.765)
SQtelec2	-0.036 (0.09)	-0.015 (0.038)	-0.051 (0.128)
Stelec1	0.096 (0.119)	0.04 (0.05)	0.136 (0.169)
SQtelec1	-0.055 (0.104)	-0.023 (0.044)	-0.079 (0.147)
MIS	-0.07 (0.167)	-0.029 (0.069)	-0.099 (0.236)
MSQ	-0.037* (0.021)	-0.016* (0.009)	-0.053* (0.029)
SIS	-3.805 (2.538)	-1.581 (1.055)	-5.387 (3.593)
SSQ	0.488 (0.594)	0.203 (0.247)	0.69 (0.84)

Notes: (*) indicates statistically significant parameter in a 95% CI, standard errors in parentheses.

With the proposed weighting, the results change considerably. Both parameters representing sanitation supply and quality were significant and had an expected signal. The total effect of a 1% increase in the logarithm of the distributed water volume *per capita*, given the average sanitation quality, negatively affects the inequality measure by 0.166 units. Quality, in this case, ponders the infrastructure provision in the sense that the greater the proportion of waterborne diseases in a given municipality, the less negative the infrastructure effects on inequality will be. This result was expected, since the returns of water and sewage provision may be higher in places with adequate treatment conditions. Since the poor may be more subject to precarious water and sewage treatment situations, expanding the sector in union with higher quality can guarantee more appropriate health conditions for the lower income group, as well as lower medicines and hospitalization expenses, perpetuating productivity gains to them and greater equality of income within the municipalities.

Regarding the transportation sector, we can note that while the supply coefficient remains non-significant, its interaction with quality is significant and has the negative sign. This result indicates that, given the existing level of transportation infrastructure, only expansion in conjunction with the improvement of this infrastructure is capable of providing lower levels of income inequality. The total effect of a 1% expansion in the highways supply, taking the average quality of the sector equal to 0.29, correlates with an appropriate income of the richest 10% being 1,975 times lower compared to the poorest 40%. The transportation quality helps to alleviate income inequality by increasing the region's comparative advantages for trade, the productivity of established businesses and the income of its workers. The reasonable explanation for this result would be that a better road network has a considerable distributional impact on household income. Since the lowest income layer in the population has a chance to access productive opportunities, their return access to better roads may be higher than the returns earned by high-income households.

In relation to the power sector, the inclusion of the interaction between supply and quality has made the coefficient of the supply variable significant, as it occurs with the coefficient of interaction. The expansion of the state power supply, taking the average quality of the sector, negatively affects income inequality (total effect of -0.24). It is noted that power quality acts as a supply-weighting factor so that the higher the quality, the greater the returns from power stock expansion in terms of lower levels of income concentration. It is argued that a greater supply of infrastructure means little about income inequality, since it is not known whether the poorest localities and the poorest people are benefiting more from this supply than the non-poor. In turn, energy infrastructure quality is represented by an index that takes into account residential consumer satisfaction issues, such as cost-benefit and quality of services provided. In this sense, while people are being served by an infrastructure with lower cost and higher quality, it is very likely that the poorest are the most benefited. This can occur because this parcel of population is the one most vulnerable to the payment of higher tariffs for power services, and also the one that suffers most from the loss of electrical appliances due to interruptions and poor quality of electricity supply services.

The parameter related to the interaction between municipal supply and quality infrastructure (MSQ) was statistically significant. Given the average quality of municipal infrastructure, a 1% increase in the Municipal Infrastructure Supply Index (MIS) affects income inequality in approximately -0.371 units. In this case, the importance of the expansion, with quality, of the services of sanitation and Internet is indicated. These findings corroborate some of the studies found in the literature (Calderón & Chong, 2004; Calderón & Servén, 2004, 2010; Seneviratne & Sun, 2013), in the sense that infrastructure quality plays an important role for localities to reach higher levels of income equality. In addition, the explanation given by Calderón and Chong (2004) that the quantitative link is stronger than the qualitative one is contradictory, since, in many cases, the beneficial infrastructure supply effect on lower levels of inequality seems to necessarily result from a joint expansion in terms of supply and quality.

The next step in the econometric analysis is to include the interactions between infrastructure supply and access. It is emphasized that the specifications set out in Table 3 are essential for the study of inequality that is conducted here, while capturing the infrastructure coverage/access effects, that is, the proportion of a certain population that, in fact, can receive the benefits of a particular infrastructure sector. Many of these indicators have not been tested in the literature, providing new evidence for the study about infrastructure and inequality.

All parameters, except for those related to sanitation access and the interaction between supply and state infrastructure access (SSA), are significant. Infrastructure supply has maintained its negative effect on income inequality. A peculiar result is found in the power sector case. The average effect of an increase of 1% in power supply, taking the average of access in the sector, on income inequality is 0.265. That is, it correlates with greater inequality. This initial effect, however, is weighted by people's access to electricity. The greater the access, the more the returns from infrastructure expansion tend to be negative, correlating with lower levels of income concentration. A particularity of the indicator of access to electricity should be mentioned. Even in 2010, the year of this indicator, the vast majority of the Brazilian population had electricity facilities, as observed by a maximum value of the indicator of population served of 100% and an average of 97%. The lowest values of this measure, with a minimum number of 27%, are found in municipalities with a high proportion of residents in rural and low-income areas, notably in the northern region of the country. The municipalities in the North of the country, in turn, have, in general, the highest indicators of income inequality. In this sense, it can be expected that the returns of an expansion in power infrastructure in these regions are still very high, while in "average" municipalities, in terms of access to energy, the effects are smaller.

Table 3 - Direct, indirect and total impacts of infrastructure supply and access on income inequality (ratio 10/40).

Variable/ Impact	Direct	Indirect	Total
	Posterior Mean	Posterior Mean	Posterior Mean
Ssanea	-0.114* (0.038)	-0.048* (0.016)	-0.161* (0.054)
SAsanea	0.053 (0.04)	0.022 (0.017)	0.076 (0.057)
Senerg	17.165* (0.877)	4.616* (0.236)	21.781* (1.113)
SAenerg	-0.174* (0.007)	-0.047* (0.002)	-0.221* (0.009)
Stelec2	-2.616* (1.265)	-1.035* (0.5)	-3.65* (1.765)
SAtelec2	-2.331* (0.38)	-0.922* (0.15)	-3.253* (0.531)
MIS	3.19* (0.383)	1.145* (0.137)	4.335* (0.52)
MSA	-0.396* (0.043)	-0.142* (0.015)	-0.539* (0.058)
SIS	-1.934* (1.091)	-0.694* (0.391)	-2.629* (1.482)
SSA	0.182 (0.121)	0.065 (0.043)	0.248 (0.164)

Notes: (*) indicates statistically significant parameter in a 95% CI, standard errors in parentheses.

The negative returns of telephony on income inequality (-6,187), in turn, are reinforced by a greater population access to fixed or cellular telephone. The effects of telecommunication expansion on inequality are enhanced while more individuals have the means to use the services. Since there is ample telephony coverage in a given municipality, more people, including the poor, can benefit from better productive opportunities, media, access to information and social interactions through telephony.

The State Infrastructure Supply Index (SIS) has a direct impact on inequality (-2.63), so that the higher the state supply, the lower the levels of municipal income concentration tend to be. Finally, a 1% change in the Municipal Infrastructure Supply Index (MIS), taking the average of the Infrastructure Access Index (IAI), generates a negative effect of 0.52 on the "10/40 Ratio." The results of the composite indices provide strong evidence that infrastructure affects inequality when more people actually access these infrastructures, rather than when such infrastructures have a greater degree of supply. In this sense, the theoretical argument made by Straub (2008) and Calderón and Servén (2014) is corroborated in that it is imperative to include variables of access and quality of infrastructure to better explain their relations with issues such as inequality and poverty.

The final procedure in the analysis of the HSAR models is to verify whether the infrastructure supply effects are maintained when all of its characteristics are included. The results of this specification are set out in Table 4. The results, in general, resemble those obtained in the access weighting in the previous subsection. Nevertheless, there are changes in the magnitude of infrastructure returns on income inequality.

At average levels of quality and access, the higher the infrastructure stocks, the smaller the municipal income disparities tend to be. The exception to this assertion is in the power sector, while supply expansion, on average, has positive effects on inequality. For comparative purposes, Table 5 describes the summary of the results of the HSAR models, showing the infrastructure supply returns of each interaction type.

Table 4 - Direct, indirect and total impacts of infrastructure supply, quality and access on income inequality (ratio 10/40).

Variable/ Impact	Direct Posterior Mean	Indirect Posterior Mean	Total Posterior Mean
Ssanea	-0.147* (0.041)	-0.061* (0.017)	-0.208* (0.058)
SIsanea	0.374* (0.173)	0.156* (0.072)	0.53* (0.245)
SAsanea	0.047 (0.039)	0.020 (0.016)	0.067 (0.055)
Senerg	34.086* (6.658)	9.163* (1.79)	43.249* (8.448)
SQenerg	-4.032* (1.511)	-1.084* (0.406)	-5.116* (1.917)
SAenerg	-0.174* (0.007)	-0.047* (0.002)	-0.221* (0.009)
Stelec2	-2.215 (5.707)	-0.884 (2.278)	-3.100 (7.986)
SQtelec2	-0.010 (0.635)	-0.004 (0.253)	-0.014 (0.888)
SAtelec2	-2.322* (0.377)	-0.927* (0.15)	-3.249* (0.527)
MIS	3.234* (0.394)	1.158* (0.141)	4.392* (0.535)
MSQ	-0.018 (0.02)	-0.007 (0.007)	-0.025 (0.027)
MSA	-0.39* (0.043)	-0.14* (0.016)	-0.529* (0.059)
SIS	-4.357* (1.983)	-1.56* (0.71)	-5.917* (2.694)
SSQ	0.336 (0.232)	0.120 (0.083)	0.456 (0.315)
SSA	0.162 (0.127)	0.058 (0.045)	0.220 (0.172)

Notes: (*) indicates statistically significant parameter in a 95% CI, standard errors in parentheses.

Table 5 - Summary of results: Infrastructure supply returns on income inequality (ratio 10/40) as weighted (average marginal effects).

Variable/ weighting	Without weighting	Quality	Access	Quality & Access
Total impacts				
Ssanea	-0.149	-0.166	-0.161	-0.176
Stransp	ns	-1.975	-	-
Senerg	ns	-0.242	0.265	0.660
Stelec2	-6.930	ns	-6.187	-2.534
Stelec1	ns	ns	-	-
SIS	ns	ns	-2.629	-5.917
MIS	-0.375	-0.317	-0.523	-0.380
Direct impacts				
Ssanea	-0.105	-0.117	-0.114	-0.124
Stransp	ns	-1.388	-	-
Senerg	ns	-0.170	0.209	0.520
Stelec2	-4.878	ns	-4.434	-2.322
Stelec1	ns	ns	-	-
SIS	ns	ns	-1.934	-4.357
MIS	-0.264	-0.224	-0.385	-0.280
Indirect impacts				
Ssanea	-0.044	-0.049	-0.048	-0.052
Stransp	ns	-0.587	-	-
Senerg	ns	-0.072	0.056	0.140
Stelec2	-2.052	ns	-1.754	-0.927
Stelec1	ns	ns	-	-
SIS	ns	ns	-0.694	-1.560
MIS	-0.111	-0.093	-0.138	-0.100

Notes: (-) indicates that there is no indicator for the sector in question; (ns) indicates not significant.

A perceptible consensus concerns the role of infrastructure access. This characteristic correlates negatively with inequality in all sectors analyzed, confirming its fundamental role in ensuring egalitarian use conditions of essential basic services such as water, sewage, Internet and electricity. In general, it can be argued that the analysis of supply indicators, on its own, does little to say about the infrastructure effects on inequality, since only three in seven supply variables tested had their significant parameters. The inclusion of infrastructure quality and, especially, access make most of the parameters significant, indicating important heterogeneities of the infrastructure characteristics for the Brazilian case.

5. CONCLUSIONS

This work applies recent advances in hierarchical and spatial modeling econometric techniques to evaluate the infrastructure effects on income inequality in Brazil in 2010. A broad database representing infrastructure in Brazil, both at the municipal and state levels is developed. We include various infrastructure sectors and characteristics. It is argued that in the Brazilian case, the possible relations between infrastructure and inequality become much more complex due to their regional and income heterogeneities. In general, the North and Northeast regions have extremely poor conditions in terms of infrastructure supply, quality and coverage, while the South and Southeast regions and, to a lesser degree, the Midwest have better indicators. In addition, there is a considerable correlation between states and municipalities with better infrastructure and lower levels of inequality.

The results obtained in this work do not only prove a negative correlation between infrastructure and income inequality, but also validate the theoretical and empirical concerns that analyze the spatial interactions and their importance in studies on infrastructure. They also provide practical warnings referring to representativeness of infrastructure variables, since there are important heterogeneities between its sectors and characteristics. Estimates obtained through hierarchical spatial models allow us to conclude that the infrastructure supply, with the exception of the power sector, contributes to lower levels of income concentration in the Brazilian municipalities. Some caveats, however, deserve attention. First, the inclusion of supply indicators alone gives weak evidence of the infrastructure effects on inequality, while most parameters were not significant. Only with the inclusion of quality and access weights, did we obtain the majority of significant parameters. The main results demonstrate that public infrastructure policies aimed at improving infrastructure quality and, essentially, expanding access are crucial for achieving lower levels of income concentration.

In order to understand the dynamic mechanisms of infrastructure interaction and income inequality in space and time, panel data models need to be specified and interpreted in future research. Due to the unavailability of data, this work was limited to cross-section analysis. In addition, we do not address possible problems of endogeneity between infrastructure and income inequality.

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APPENDIX C

Table C1 - Infrastructure variables.

Type	Name	Level	Period	Definition	Source
Supply	*Ssanea*	Municipal	2008	Log of the treated water volume distributed per day (m³) per capita	IBGE
	Sransp	State	2004-2010	Log of total length of paved and unpaved roads (km) per capita	CNT & IBGE
	Snerg	State	2004-2010	Residential Electricity Consumption (GwH) per capita	ANEEL & IBGE
	Stelec1	Municipal	2007-2010	Log of internet gateway per capita	ANATEL & IBGE
	Stelec2	State	2007-2010	Log of the sum of fixed and mobile telephony gateway per capita	ANATEL & IBGE
	SIS	State	-	1st Main Component of Stransp, Senerg and Stelec2 variables	-
	MIS	Municipal	-	1st Main Component of the variables Ssanea and Stelec1	-
Quality/ Inefficiency	*Isanea*	Municipal	2010	Proportion of hospitalizations due to waterborne diseases	DATASUS
	Qtransp	State	2004-2010	Percentage of highways classified as in good or excellent condition	CNT & IBGE
	Qenerg	State	2004-2010	Log of the ANEEL Consumer Satisfaction Index (IASC)	ANEEL
	Qtelec1	Municipal	2007-2010	Percentage of internet accesses with speeds above 512 Kbps	ANATEL
	Qtelec2	State	2007-2010	Completed original call rate completed	ANATEL
	SIQ	State	-	1st Main Component of Qtransp, Qenerg and Qtelec2 variables	-
	MIQ	Municipal	-	1st Main Component of the Isanea and Qtelec1 variables	-
Access	*Asanea*	Municipal	2010	Households with access to sewage (%)	Censo Demográfico
	Aenerg	Municipal	2010	Households with access to electricity (%)	Censo Demográfico
	Atelec	Municipal	2010	Households with access to cell phones or landlines (%)	Censo Demográfico
	IAI	Municipal	2010	1st Main Component of the variables Asanea, Aenerg and Atelec	-
Weighting	*SSQ*	State	-	Multiplication between SIS and SIQ	-
	MSQ	Municipal	-	Multiplication between MIS and MIQ	-
	SSA	-	-	Multiplication between SIS and IAI	-
	MSA	Municipal	-	Multiplication between MIS and IAI	-

Table C2 - Dependent and control variables description.

Type	Variable	Definition	Source
Dependent	*r1040*	Ratio 10% richer/40% poorer (household income per capita)	Atlas do Desenvolvimento
Control (municipal)	*va_ind*	Natural logarithm of the value-added of per capita industry	IBGE
	va_agro	Natural logarithm of the aggregate value of agriculture per capita	IBGE
	va_ser	Natural logarithm of the value added of the services sector per capita	IBGE
	idhm_e	Natural Logarithm of the Human Development Index of Education	Atlas do Desenvolvimento
	idhm_l	Natural Logarithm of the Human Development Index of Health	Atlas do Desenvolvimento
	pformal	Formalization degree of employed persons	Atlas do Desenvolvimento
	mort	Infant mortality: the probability of dying between birth and the exact age of 5 years per 1000 live births	Atlas do Desenvolvimento
	pop	Natural logarithm of the total population	IBGE

Table C3 - Descriptive statistics of the variables used in the experiment on municipal income inequality and infrastructure.

Variable	Mean	Standard Deviation	Minimum	Maximum	Variable	Mean	Standard Deviation	Minimum	Maximum
r1040	14.40	9.22	0	221	*Isanea*	0.06	0.05	0	0.41
va_ind	0.96	1.32	-1.69	6.60	*Qtransp*	0.29	0.20	0.03	0.74
va_agro	1.26	1.34	-8.62	5.28	*Qenerg*	4.13	0.09	3.89	4.23
va_ser	2.01	0.76	-0.14	5.36	*Qtelec1*	0.35	0.19	0.00	1.00
idhm_e	4.01	0.17	3.03	4.40	*Qtelec2*	73.73	1.12	70.17	76.94
idhm_l	4.38	0.06	4.21	4.49	*Asanea*	0.30	0.32	0	1
pformal	43.73	19.22	2.97	89.11	*Aenerg*	97.24	5.93	27.41	100
mort	21.47	7.30	9.98	50.94	*Atelec*	0.78	0.16	0.12	0.98
pop	9.42	1.15	6.69	16.23	*SIS*	2.35	1.32	0.26	5.00
Ssanea	13.15	2.87	0	21.71	*MIS*	6.00	1.16	0.62	8.69
Stransp	2.49	0.43	1.26	3.80	*SIQ*	2.69	1.38	0.07	4.99
Senerg	13.03	1.16	9.70	14.77	*MIQ*	6.00	1.07	0.50	9.19
Stelec2	3.53	0.74	1.24	4.73	*IAI*	9.02	1.35	0.69	11.18
Stelec1	6.25	1.61	0.29	10.29					

APPENDIX D

Table D1 - Principal components: eigenvalues.

Indicator/ Component	Eigenvalue		
	Component 1	Component 2	Component 3
Supply (State)	1.30	0.98	0.58
Supply (Municipal)	1.15	0.81	-
Quality (Estadual)	1.26	0.97	0.68
Quality (Municipal)	1.07	0.92	-
Access	1.36	0.85	0.65

APPENDIX E

Table E1 – Global Moran's I Statistics.

Variable	Moran's I	Prob	Variável	Moran's I	Prob
Inequality			***Municipal Infrastructure***		
r1040	0,446	0.00	*Ssanea*	0,203	0.00
			Stelec1	0,615	0.00
Controls			*Isanea*	0,586	0.00
va_ind	0,496	0.00	*Qtelec1*	0,284	0.00
va_agro	0,622	0.00	*Asanea*	0,739	0.00
va_ser	0,573	0.00	*Aenerg*	0,627	0.00
idhm_e	0,693	0.00	*Atelec*	0,752	0.00
idhm_l	0,737	0.00	***Municipal Infrastructure***		
pformal	0,773	0.00	*Stransp*	0,022	0.31
mort	0,740	0.00	*Senerg*	0,474	0.00
pop	0,336	0.00	*Stelec2*	0,576	0.00
			Qtransp	0,523	0.00
			Qenerg	0,522	0.00
			Qtelec2	0,071	0.19

APPENDIX G

Table G1 - Infrastructure supply effects on income inequality (10/40 ratio) using HSAR model.

Variable/Sector	**Sanitation**		**Transportation**		**Power**		**Telephony**		**Internet**		**Infrastructure**	
	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE
Variáveis de controle												
Constante	142.53	9.68	127.59	9.47	130.42	9.84	132.23	9.55	123.03	9.56	140.24	9.40
va_ind	-0.42	0.13	-0.43	0.13	-0.43	0.13	-0.43	0.13	-0.42	0.13	-0.44	0.13
va_agro	-0.07^{ns}	0.10	-0.09^{ns}	0.10	-0.08^{ns}	0.10	-0.07^{ns}	0.10	-0.08^{ns}	0.10	-0.08^{ns}	0.10
va_ser	2.10	0.28	2.08	0.28	2.05	0.28	2.06	0.29	2.01	0.30	2.16	0.29
idhm_e	-15.40	1.01	-15.62	1.01	-15.57	1.01	-15.54	1.04	-15.73	1.03	-15.23	1.04
idhm_l	-15.72	2.37	-15.86	2.76	-13.58	2.46	-10.21	2.68	-11.88	2.32	-15.05	2.33
pformal	-0.06	0.01	-0.06	0.01	-0.06	0.01	-0.06	0.01	-0.06	0.01	-0.06	0.01
mort	-0.24	0.03	-0.24	0.03	-0.23	0.03	-0.20	0.03	-0.21	0.03	-0.24	0.03
pop	0.90	0.13	0.86	0.13	0.87	0.13	0.87	0.13	0.84	0.13	0.92	0.13
Infrastructure												
Ssanea	-0.10	0.04										
Stransp			1.39^{ns}	1.55								
Senerg					0.57^{ns}	0.97						
Stelec2							-5.12	1.81				
Stelec1									0.08^{ns}	0.12		
SIS											-1.78^{ns}	1.14
MIS											-0.26	0.13
Spatial parameters												
ρ	0.31	0.02	0.31	0.02	0.31	0.02	0.31	0.02	0.31	0.02	0.31	0.02
λ	0.53	0.20	0.80	0.20	0.61	0.18	0.62	0.19	0.55	0.20	0.44	0.20
Random effects												
$\sigma_e^2\ (municipal)$	31.65	11.90	31.25	12.44	29.90	11.64	19.16	7.53	29.96	11.78	30.04	11.41
$\sigma_u^2\ (state)$	48.25	0.93	48.31	0.95	48.27	0.93	48.33	0.93	48.27	0.93	48.29	0.94
Model adjustment indicators												
Deviance information criterion (DIC)	52249.27		52262.95		52251.74		52260.65		52255.43		52251.17	
Log likelihood	-26124.98		-26132.30		-26126.54		-26130.85		-26128.01		-26126.21	
Pseudo R²	0.39		0.39		0.39		0.39		0.39		0.39	

Notes: Estim., Estimates; SE, standard error; ns indicates not significant.

Table G2 – Infrastructure supply and quality effects on income inequality (ratio 10/40) using HSAR model.

Variable/Sector	Sanitation		Transportation		Power		Telephony		Internet		Infrastructure	
	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE
Ssanea	-0.136	0.041										
SIsanea	0.371	0.174										
Stransp			1.690ns	1.995								
SQtransp			-6.994	3.851								
Senerg					30.275	8.222						
SQenerg					-7.137	1.964						
Stelec2							-1.973ns	7.425				
SQtelec2							-0.039ns	0.099				
Stelec1									0.100ns	0.124		
SQtelec1									-0.055ns	0.103		
MIS											-0.069ns	0.164
MSQ											-0.037	0.020
SIS											-3.735ns	2.491
SSQ											0.479ns	0.583
ρ	0.310	0.018	0.311	0.018	0.312	0.018	0.308	0.018	0.310	0.0181	0.308	0.018
λ	0.555	0.213	0.417	0.232	0.289	0.268	0.661	0.189	0.564	0.193	0.516	0.193
$\sigma_e^2\ (municipal)$	32.1	11.8	31.3 12.4	28.4	10.2	19.6	7.88	30.4 11.9	29.8	11.7	32.1	11.8
$\sigma_u^2\ (state)$	48.2	0.94	48.3 0.94	48.2	0.93	48.3	0.93	48.2 0.94	48.2	0.93	48.2	0.94
DIC	52238.13		52256.60		52261.79		52260.980		52258.42		52247.940	
Log likelihood	-26119.53		-26128.87		-26131.27		-26131.150		-26129.51		-26124.300	
Pseudo R²	0.392		0.391		0.390		0.390		0.390		0.392	

Notes: Estim., Estimates; SE, standard error; ns indicates not significant.

Table G3 - Infrastructure supply and access effects on income inequality (ratio 10/40) using HSAR model.

Variable/Sector	Sanitation		Power		Telephony		Infrastructure	
	Estim.	SE	Estim.	SE	Estim.	SE	Estim.	SE
Ssanea	-0.111	0.037						
SAsanea	0.050ns	0.037						
Senerg			17.190	0.879				
SAenerg			-0.173	0.007				
Stelec2					-3.279	1.585		
SAtelec2					-2.280	0.372		
MIS							3.146	0.377
MSA							-0.391	0.042
SIS							-2.642	1.489
SSA							0.180ns	0.120
ρ	0.310	0.019	0.220	0.018	0.298	0.019	0.275	0.018
λ	0.574	0.194	0.468	0.225	0.577	0.190	0.541	0.209
$\sigma_e^2\ (municipal)$	30.85	11.48	12.41	4.72	20.22	8.02	22.99	8.59
$\sigma_u^2\ (state)$	48.21	0.92	43.67	0.84	48.02	0.92	47.04	0.90
DIC	52241.660		51132.240		52192.370		51960.090	
Log likelihood	-26121.250		-25566.560		-26096.430		-25980.690	
Pseudo R²	0.391		0.465		0.397		0.417	

Notes: Estim., Estimates; SE, standard error; ns indicates not significant.

Table G4 - Infrastructure supply, quality and access effects on income inequality (ratio 10/40): spatial hierarchical model (HSAR).

Variable/Sector	Sanitation Estim.	SE	Power Estim.	SE	Telephony Estim.	SE	Infrastructure Estim.	SE
Ssanea	-0.145	0.040						
SIsanea	0.369	0.171						
SAsanea	0.046[ns]	0.038						
Senerg			35.499	6.934				
SQenerg			-4.483	1.680				
SAenerg			-0.172	0.007				
Stelec2					-3.027[ns]	7.798		
SQtelec2					-0.002[ns]	0.109		
SAtelec2					-2.269	0.368		
MIS							3.178	0.387
MSQ							-0.018[ns]	0.020
MSA							-0.383	0.043
SIS							-4.573	2.082
SSQ							0.543[ns]	0.374
SSA							0.155[ns]	0.121
ρ	0.309	0.018	0.219	0.018	0.298	0.018	0.273	0.018
λ	0.611	0.194	0.056	0.303	0.586	0.199	0.590	0.182
$\sigma_e^2\ (municipal)$	32.09	11.69	11.61	4.33	20.12	7.93	24.33	9.65
$\sigma_u^2\ (state)$	48.18	0.91	43.67	0.85	48.01	0.92	47.03	0.89
DIC	52224.360		51132.010		52191.290		51953.320	
Log likelihood	-26112.570		-25566.210		-26096.400		-25977.290	
Pseudo R²	0.392		0.465		0.397		0.418	

Notes: Estim., Estimates; SE, standard error; ns indicates not significant.