# Trade and Infrastructure: their relationship in Brazilian states

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**Abstract**

An improvement of infrastructure and logistics, when integrating production and businesses among between different areas or countries, reduces the costs of trade and promotes overall wealth. However, much more analysis has been done on the relationship between infrastructure and international trade than the regional or interstate trade levels. So, the main goal of this study was to estimate the existing relationship between available infrastructure services and trade volume among the Brazilian states. It was created an indicator of the existent infrastructure, in different states, that was related to the commercial flow among them. The state of São Paulo is the one which presents the largest values, having the highest indicators, in six out of eleven indicators considered. The gravity model, proposed for the analysis, presented coherent and significant estimates for the included variables. GDP from the importer state was the most important variable to explain the export flows. The infrastructure index was important in explaining exports. The estimated coefficient was positive, indicating increases that were more than proportional in exports among the Brazilian states (1.18 percent). As a conclusion, it can be said that, if investment in infrastructure in the poorest states continues to be inferior to that of the richest states, their share in production and national trade will continue to shink.

**Keywords:** Trade, Infrastructure, Gravity model, Brazilian states

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## 1. Introduction

Trade costs are frequently mentioned as an important determinant of the marketed volume of a product. According to Anderson and van Wincoop (2004), trade costs include all expenses incurred in getting goods to the final user, minus the marginal cost of producing the goods, such as transportation costs, policy barriers (tariff and non-tariff), information costs, contract and distribution costs (wholesale and retail). In economic literature, it is common to find statements about the negative impact of such costs on trade volume. In the case of international trade, many studies show that the process of economic integration and the gains from trade among countries, depend not only on liberalization of barriers, but on the quality of the infrastructure and related services. An improvement of infrastructure and logistics, when integrating production and businesses between different areas or countries, reduces the costs of trade and promotes overall wealth.

A study by the World Bank (WORLD BANK, 2001) showed that the effective rate of protection proportioned by transport costs, for instance, can be higher than that provided by tariffs. In the case of Latin America and the Caribbean countries, protection provided by transportation costs was five times larger than that provided by tariffs, and among 216 commercial partners of the United States, 168 of them presented barriers related to transportation costs that were larger than those related to tariff barriers.

Wilson et. al. (2003) analyzed the relationships between four measures of international trade facilitation (port efficiency, customs environment, regulatory environment and use of e-business) and the flow of goods among members of the Asia-Pacific Economic Association (APEC), concluding that the improvement in port efficiency alone would account for half of the increase in trade.

Limao and Venables (2001) emphasized the interdependence of trade costs and infrastructure, measured as the average density of the road network, the rail network and the number of telephone lines per capita, concluding that a deterioration of infrastructure from the median to the 75th percentile of destinations raises transport costs by 12 percent, reducing trade up to 28 percent.

A good review of studies showing the relevance of trade costs as determinative of marketed volume was published by Anderson and Van Wincoop (2004). Many of the studies showed that integration between certain countries and areas results from low transportation costs and other infrastructure services, in spite of the persistence of several restrictions to trade, known as "soft" and "hard" barriers. The "soft" barriers are those related to measures of facilitating the atmosphere for businesses (such as documentation and procedures), while the "hard" barriers are those related to infrastructure or facilitation of the transport and movement of goods.

However, much more analysis has been done on the relationship between infrastructure and international trade than the regional or interstate trade levels. The existence of well-delineated and supervised borders between countries contributes to the fact that their commercial, technological, legal and cultural politics act in different ways in terms of the production and costs of goods and services. For that reason, information and research on the flow of goods and services are more frequent done among countries than *inside* countries.

In the case of Brazil, for instance, studies on regional or interstate trade are rare, in spite of the size and the structural differences within the country. Studies that have been done on regional trade, include those from Hidalgo and Vergolino (2001), Istake (2003), Almeida and Silva (2006), and Silva et. al. (2007). Also, there are a few studies that attempt to relate infrastructure with economic growth and trade. One of those studies was undertaken by Castro et. al. (2001), who used data from 1985 to analyze the impact of logistical (transport) costs on the Brazilian interstate trade. The authors concluded that trade flows among states having a higher proportion of agricultural production are the most affected by logistical costs.

Recently, however, there have been studies corroborating the hypothesis that higher spending on infrastructure have a direct effect on productivity and economic growth. These include the studies of Ferreira (1994 and 1996), Fortunato and Silva (2007) and Costa da Silva et. al. (2007). In all those cases, however, the authors used a macroeconomic approach, with indicators of infrastructure measured in terms of public expenditures affecting growth, measured in terms of Gross Domestic Product (GDP).

Knowledge about the differences in the Brazilian states' infrastructure and on its role in determining the volume of internal trade would be helpful to understanding a causal relationship that, according to Wilson, Mann and Otsuki (2003), "seems simple theoretically, but is complex and challenging in terms of its specification and empirical estimation."

So, the main goal of this study is to estimate the existing relationship between available infrastructure services and trade volume among the Brazilian states. To do so, it is necessary to create indicators of the existing infrastructure for different states and to determine their relationship to the commercial flow of goods.

## 2. Methodology

The gravity model is commonly used in international trade literature to explain a great proportion of bilateral trade volume. In its simpler form, the gravity model relates the flow of bilateral trade to each commercial partner's economic size, usually represented by their respective Gross Domestic Products and by the physical distance between them. In logarithmic form, it could be expressed as:

$$\ln(X_{ij}) = \beta_0 + \beta_1 \ln(Y_i) + \beta_2 \ln(Y_j) + \beta_3 \ln(D_{ij}) + \mu \quad (1)$$

The logic behind the gravity model is that trade volume is promoted by the economical mass of each country (GDPs) and inhibited by the distance between them. A high level of income in exporting countries indicates high levels of production and readiness for exports, while a high level of income in importing countries indicates a larger propensity to import goods. The variable distance would represent a resistance to the commercial flows, given by elements of economical nature, such as the costs of transportation and information costs.

Therefore, in equation (1), coefficients of the variables $Y_i$ and $Y_j$ are expected to be positive, while the coefficient of variable $D_{ij}$ is expected to be negative.

It is common to introduce other variables in the basic form of the gravity model of equation (1). Linnemann (1966), for instance, mentioned by Azevedo (2004), introduced the size of the population as a means to weight production to the domestic market and to the external market. Frankel et al. (1995) introduced dummy variables for pairs of countries that share a common border or common languages, besides those used to capture the effects of a country's adhesion to a preferential trade agreement. Those variables are expected to be positive, since neighboring countries tend to trade more amongst each other; a common language facilitates commercial exchanges; and participation in preferential trade agreements also increases trade volume among member countries.

In this study, in addition to the variables GDP and distance, we considered the availability of physical infrastructures such as highways, railroads, ports and airports, and communication infrastructures, such as electric power, telephony and access to the Internet. To determine the impact of those variables on bilateral trade, an index of infrastructure was constructed and used in the model, which shows the relative position of each state on those selected variables. In their construction of trade facilitation indicators, Wilson et al. (2003) used variables that were indexed to the average of all the APEC members' value, generating indicators with very different standard deviations, given the different units of measure. Here, the infrastructure index (II), is constructed by using the same formula used by the United Nations (UNITED NATIONS, 2006) to calculate the Human Development Index (HDI):

$$II = \frac{(Actual - Mínimum)}{(Máximum - Mínimum)} \tag{2}$$

with values of expression (2) corresponding to current values of the maximum and minimum for each infrastructure variable selected for the Brazilian states. The advantage of using this kind of formula to calculate an index is that -- in addition to allowing the aggregation of variables with different units of measure -- it standardizes the variation width in the interval zero to one (0-1).

Variables included in the indicators of infrastructure and load movement were: extension of highways and railroads, by km$^2$; consumption of electric power, per one thousand inhabitants; lines of fixed and mobile telephones and access to the Internet, per one thousand inhabitants; movement of containers in fluvial ports and of total aerial load; total of passengers and landings and takeoffs, in airports. However, to be used in the gravity equation, the indexes for each variable were aggregated in a unique indicator, simply adding the individual indexes (Σ II), under the assumption that, the larger the value of that indicator, the larger the trade facilitation proportionate by the available infrastructure.

The basic structure of the model, in the logarithmic form, is presented by equation (3):

$$\ln(X_{ij}) = \beta_0 + \beta_1 \ln(Y_i) + \beta_2 \ln(Y_j) + \beta_3 \ln(D_{ij}) + \beta_4 \ln(\Sigma II) + \beta_5 \ln(ADJ_{ij}) + \mu \qquad (3)$$

In addition to variables $Y_i$, $Y_j$ and $D_{ij}$, which were previously defined, equation (3) includes the following explanatory variables: the indicator of infrastructure and load movement (Σ II) and a dummy variable to capture the effect of adjacency ($ADJ_{ij}$), which both assume the value of one if two states are adjacent, and if not, zero. $X_{ij}$ represents the total exports of state *i* to state j.

Data on exports among the 26 Brazilian states and the Federal District were obtained from Vasconcelos and Oliveira (2006). Those on GDP were obtained from the Brazilian Institute of Geography and Statistics (IBGE), while distances in kilometers were obtained from the site www.areaseg.com and represent physical distances between the capitals of each state. The infrastructure variables, considered in the calculation of each index and their respective sources, were: extension of railroads and paved highways/km$^2$ – Agência Nacional de Transportes Terrestres; consumption of electric power, per capita - Ipea Data; total number of home-internet users - CETIC; lines of fixed and mobile telephones, per one thousand inhabitants - ANATEL; movement in the number of containers (fluvial and total aerial loads) in tons - Ministry of the Transports, ANTAq and INFRAERO; passenger movement and number of landings and takeoffs in airports - INFRAERO. All data are from 1999, restricted to that year, due to the unavailability of information on trade among states for other years.

**3. Results**

Before presenting the results from the estimated equation, we discuss the indexes calculated for each variable, for different regions of the country.

Variables indicating the stock of infrastructure and load movement are the same 10 variables used by De (2006), plus a variable for total “number of internet users at home," as an indicator of access to the internet in different states. Table 1 shows the average, minimum and maximum values for each variable, followed by the corresponding Brazilian states. Table 1 also presents an average index calculated for those variables.

Notably, except for the variables electric energy and highways, the average values are low with a large variance, indicating a high level of asymmetry in the available infrastructures among the Brazilian states. The state of São Paulo is the one which presents the largest values, having the highest indicators in six out of eleven indicators. The Federal District has the highest values for the variables of highway density and cellular telephony. Rio Grande do Sul presents the largest indicator for fixed telephony, while the states of Rio de Janeiro and Espírito Santo present the largest values for railroads and fluvial transport, respectively.

The minimum values are those for the states of the North and Northeast regions. Here, the state of Roraima presents the smallest values, followed by the states of Tocantins and Maranhão. The state of Piauí showed the smallest indicator for electric power, and Amapá, the smallest indicator for highway density.

Table 1 - Average calculated index and average minimum and maximum values for each variable

| Variable | Description | Average Index | Minimum Value | State | Maximum Value | State |
|---|---|---|---|---|---|---|
| Aerial Load | Total aerial load, in kg | 46,039.884 (0.116) | 1,085.262 | TO | 630,505.218 | SP |
| Mobile Telephony | Access to mobile service, per one thousand inhabitants | 0.113 (0.098) | 0.039 | MA | 0.333 | DF |
| Containers | Movement of containers in ports | 57,032 (0.071) | 0.000 | AC, DF, GO, MA, MG, MS, MT, RR, SE,TO | 547,455 | SP |
| Electric Power | Consumption of electric power (MWh), per one thousand inhabitants | 1.302 (0.155) | 0.464 | PI | 2.524 | SP |
| Railroads | Extension of the Railroads / $Km^2$ | 0.007 (0.104) | 0.000 | AC, AM, MT, RO, RR, TO | 0.027 | RJ |
| Internet | Access to internet, per one thousand inhabitants | 129.630 (0.407) | 6.673 | RR | 762.925 | SP |
| Passengers | Number of passengers in airports | 2,329,790 (0.250) | 81,470 | TO | 23,039,919 | SP |
| Landings and Takeoffs | Number of landings and takeoffs in airports | 75,787 (0.084) | 11,218 | RR | 569,161 | SP |
| Highways | Extension of paved highways/ $km^2$ | 0.044 (0.163) | 0.001 | AP | 0.128 | DF |
| Fixed Telephony | Fixed telephony (residential and public), per one thousand inhabitant | 77.664 (0.262) | 42.041 | MA | 165.467 | RS |
| Fluvial Transport | Loads in general in ports / tons | 16,137,403 (0.338) | 0.000 | AC, DF, GO, PI, RR, TO | 104,288,675 | ES |

To emphasize the differences in the available Brazilian states' infrastructure, we also constructed five sub-indexes based on the previously selected indicators: Index 1 - Transports (road and rail); Index 2 - Consumption of electric power; Index 3 - Communication (internet, fixed and mobile telephony), Index 4 – Load movement (containers, aerial, and fluvial loads); and Index 5 - Aerial traffic (landings, takeoffs, and number of passengers). The sub-indexes are presented in Figure 1, for each of the five regions of the country. Here, the regional averages of the sub-indexes were calculated, and the highest value of each was set equal to one, with the other values re-calculated, relative to that value. In this way, the differences among the indicators become more evident. It can be seen in Figure 1 that the Southeast region has the largest infrastructure indexes, except for Index 3 - communication, where the South region presents the highest value. Following the Southeast region are the indexes of the South, West, Northeast, and North regions. Notably, the Northeast region supplants the West region in transport, consumption of electric power and load movement. On the other hand, the West region presents infrastructure levels of communication and aerial movement that are larger than those of the Northeast region, due mostly to the high values of those indicators to the Federal District. The North region is the least endowed with infrastructure in general, surpassing only the Northeast region in the load movement indicator (containers, aerial, and fluvial loads).

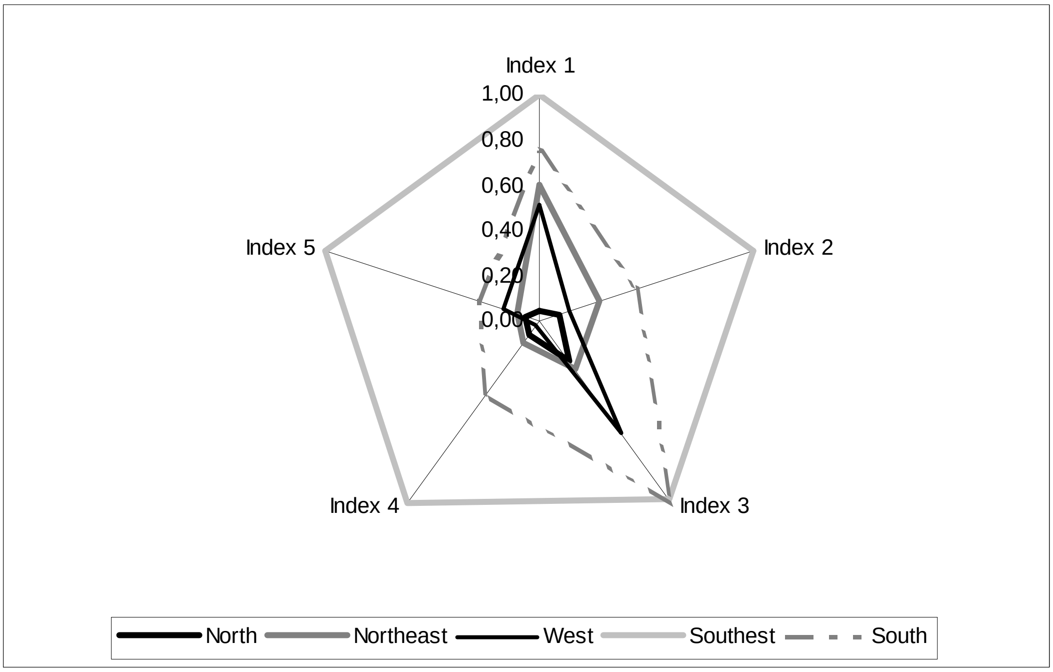


Figure 1 - Relative availability of infrastructure in Brazil, by regions (1999).

As opposed to the Human Development Index, in which a weighted average of different variables is used, in this case, in order to capture the effects of infrastructure indicators on bilateral trade, individual infrastructure indicators were added in an attempt to represent the stock of available infrastructure in each state. That variable was then included in the estimating equation (3), with results presented in Table 2. The correlation coefficients of the variables used are presented in Table A1, in the Appendix. We have used 681 observations from bilateral trade flows. In 21 cases, there was no trade on goods among the states.

Column (1) shows the estimates obtained by applying Ordinary Least Squares in equation (3). It can be seen that the results were generally good, with a high value for $R^2$ (81%). Estimated coefficients are significant at one percent and present the expected signs, except the coefficient for the infrastructure index, which is non-significant and presented an opposite sign from that expected.

Tests for autocorrelation and heteroskedasticity indicated no problems. However, the correlation matrix in Table A1 shows high correlation coefficients between the variables of the state's GDP and the infrastructure index (above 88%), indicating problems of collinearity. An auxiliary regression estimate between the states' exporters' GDPs and the variable infrastructure index for the same states (Table A2) presented -- after correction for autocorrelation -- a value for $R^2$ of 98.6%, indicating an almost perfect relationship between those variables. Such a result was expected, and shows that better infrastructure prevails in higher income states.

Table 2 – Regression results on intra-state exports

| **Variables** | **Equations** | |
|---|---|---|
| | **(1)** | **(2)** |
| Constant | -22.2091*<br>(1.5011) | -5.9945*<br>(1.1279) |
| Log $Y_i$ | 0.9725*<br>(0.0717) | --- |
| Log $Y_j$ | 1.3674*<br>(0.0336) | 1.3667*<br>(0.0402) |
| Log $D_{ij}$ | -0.7674*<br>(0.0850) | -0.7280*<br>(0.1096) |
| Log $\Sigma II_i$ | -0.0934<br>(0.1075) | 1.1838*<br>(0.0734) |
| Dummy $Adj_{ij}$ | 0.9894*<br>(0.1602) | 1.1261*<br>(0.1862) |
| R-squared ($R^2$) | 0.8143 | 0.7734 |
| F-statistic | 592.2586* | 465.32* |
| Durbin-Watson | 1.9588 | 2.0610 |

Values in parenthesis are the standard errors. The "*"denotes significance at the one percent level.

To correct for this problem, equation (3) was again estimated without the variable $GDP_i$, the results of which are presented in column (2). With this correction, all variables are significant and present the expected signs. The coefficient estimated for the variable $GDP_j$ indicates, on average, that increases of one percent in an importer state's GDP increases state exporters' exports by 1.36 percent. Variable distance is inversely proportional to exports, and increases of one percent in distance would reduce exports by 0.72 percent, on average. The estimated value for the dummy variable of adjacency corroborates that result, revealing that states sharing a common border tend to trade three times more among each other (an exponential of 1.126) than those states not sharing a border. The infrastructure index was important in explaining exports. The estimated coefficient was positive, indicating increases that were more than proportional in exports among the Brazilian states (1.18 percent). The effect on trade from the state exporter's GDP should be similar, given the high collinearity with the infrastructure index (having a correlation coefficient of 0.99). The basic point is that when a state reinforces its infrastructure (highways, ports, airports and communication), bilateral trade tends to expand even though the importer state (or country) may not improve its own infrastructure, because dispatch of products is more important in regulating bilateral trade than internal distribution in the importer country. However, if the importer state (or country) also improves its infrastructure, that will have an even greater impact on trade between the two.

Equations using infrastructure sub-indexes were also estimated. The results, presented in the Table 3, were quite reliable compared to those achieved with the aggregated infrastructure index. Problems of collinearity persisted and were amplified among those infrastructure variables.

In column (1), the signs of the coefficients for sub-indexes 1 (transports) and 5 (aerial movement) proved contrary to the expected results, though the value is without statistical significance for sub-index 5. An auxiliary regression of the variable for sub-index 1 (transports) as a function of the others indexes, presented a $R^2$ of 98.1% with statistical significance for all coefficients at one percent, a typical case of high collinearity among them. The equations presented in columns (2) and (3), were estimated sequentially without sub-indexes 5 and 1, while that of column (4) shows the isolated effect of sub-index 1 (transport) on trade flows.

The coefficients of the variables for GDP, distance and adjacency are relatively stable and independent of the estimated equation. Considering infrastructure variables as sub-indexes did not change the GDP coefficient, but it slightly increased the coefficient of the variable distance (average = 0.806) and slightly reduced the coefficient of the variable adjacency (average = 0.931). High correlation among sub-indexes does not allow any individualized analysis of their effects on exports, but does show the existence of a strong relationship between infrastructure and trade flows.

Table 3 – Regression results for the equations with infrastructure sub-indexes.

| Variables | Equations | | | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Constant | -2.9259** (0.9954) | -2.9472** (0.9934) | -3.7660** (0.9370) | -4.4617** (1.3461) |
| Log $Y_j$ | 1.3514** (0.0344) | 1.3515** (0.0344) | 1.3600** (0.0334) | 1.3751** (0.0527) |
| Log $D_{ij}$ | -0.8085** (0.0901) | -0.8059** (0.0898) | -0.7174** (0.0842) | -0.8924** (0.1191) |
| *Dummy* $Adj_{ij}$ | 0.8953** (0.1659) | 0.8957** (0.1658) | 1.0529** (0.1567) | 0.8822** (0.1879) |
| Sub-index 1 | -0.1017* (0.0475) | -0.0940* (0.0437) | --- | 0.5151** (0.0726) |
| Sub-index 2 | 0.8083** (0.0727) | 0.7897** (0.0569) | 0.7324** (0.0531) | --- |
| Sub-index 3 | 0.4184** (0.1323) | 0.3738** (0.0760) | 0.3326** (0.0744) | --- |
| Sub-index 4 | 0.0736* (0.0372) | 0.0683* (0.0349) | 0.0833** (0.0339) | --- |
| Sub-index 5 | -0.0373$^{ns}$ (0.0907) | --- | --- | --- |
| R-squared ($R^2$) | 0.8209 | 0.8208 | 0.8174 | 0.7335 |
| F-Statistic | 357.5521 | 409.1506 | 486.6660 | 356.2259 |
| Durbin-Watson | 1.9910 | 1.9911 | 1.9575 | 2.2557$^{\#}$ |

Values in parenthesis are standard errors of the estimates. * *, * denote significance at the levels of 1 and 5 percent, respectively. *ns* denotes absence of statistical significance, while # denotes correction for autocorrelation.

The coefficients of the variables for GDP, distance and adjacency are relatively stable and independent of the estimated equation. Considering infrastructure variables as sub-indexes did not change the GDP coefficient, but it slightly increased the coefficient of the variable distance (average = 0.806) and slightly reduced the coefficient of the variable adjacency (average = 0.931). High correlation among sub-indexes does not allow any individualized analysis of their effects on exports, but does show the existence of a strong relationship between infrastructure and trade flows.

The results obtained have some limitations, since problems of endogeneity cannot be ignored. Trade infrastructure can be improved with an increase in trade flows among the states.

In that case, the estimated coefficients for the infrastructure indexes would be biased upwards. Correcting this problem using instrumental variables for the infrastructure variables creates difficulties in finding exogenous variables to be the instruments (usually, the actual instruments are correlated with trade flows). The use of time series was not possible given the lack of series on trade flows.

## 4. Conclusions

The analysis in this paper has demonstrated the importance of infrastructure on trade flows between Brazilian states. Construction of an infrastructure index for 26 states and the Federal District and its use as an explanatory variable in a model of interstate trade, showed that increments in transport and communication infrastructures would proportionally increase trade flows. However, the existing asymmetries in infrastructure among states and regions of the country were also evident. The main challenges for the decision-makers -- mainly in those states with the worst indicators -- would be to improve the logistical services and related infrastructures, in the short- and medium-runs, making a significant impact on competitiveness and trade flows possible. If investment in infrastructure in the poorest states continues to be inferior to that of the richest states their share in production and national trade will continue to shrink.

Other studies in this area should focus on the following points: first, the analysis was performed using aggregated data. A decomposition of commercial flows and infrastructure indicators, using appropriate methods, could capture specific relationships among them. Second, if possible, future research should use a larger and more recent database to capture the evolution of the relationships seen here. Finally, endogeneity should be taken into account, in order to identify the appropriate instrumental variables or other methods to solve the problem.

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## Appendix

Table A1 - Correlation matrix

| | $Log(X_{ij})$ | $Log(Y_i)$ | $Log(Y_j)$ | $Log(D_{ij})$ | $Log(\Sigma II_i)$ | $D\_Adj_{ij}$ | $Log(\Sigma II_j)$ |
|---|---|---|---|---|---|---|---|
| $Log(X_{ij})$ | 1,0000 | 0,4307 | 0,7076 | -0,4698 | 0,3832 | 0,3028 | 0,5947 |
| $Log(Y_i)$ | 0,4307 | 1,0000 | -0,0709 | -0,1060 | 0,8872 | 0,0232 | -0,0593 |
| $Log(Y_j)$ | 0,7076 | -0,0709 | 1,0000 | -0,2092 | -0,0574 | 0,0560 | 0,8847 |
| $Log(D_{ij})$ | -0,4698 | -0,1060 | -0,2092 | 1,0000 | -0,1444 | -0,6122 | -0,2489 |
| $Log(\Sigma II_i)$ | 0,3832 | 0,8872 | -0,0574 | -0,1444 | 1,0000 | -0,0249 | -0,0554 |
| $D\_Adj_{ij}$ | 0,3028 | 0,0232 | 0,0560 | -0,6122 | -0,0249 | 1,0000 | 0,0068 |
| $Log(\Sigma II_j)$ | 0,5947 | -0,0593 | 0,8847 | -0,2489 | -0,0554 | 0,0068 | 1,0000 |

Table A2 - Variable GDPi as function of infrastructure. MQO.

| Variable | Coefficient | Standard Error | $R^2$ | F-statistic | Dw |
|---|---|---|---|---|---|
| Intercept | 16,9045* | 0,2368 | 0,9861 | 24.142,85 | 1,9751 |
| Index Infrastructure. | 0,9398* | 0,0417 | | | |
| AR(1) | 0,9737* | 0,0086 | | | |

* indicates statistical significance at the level of 1% of probability.