# The impact of infrastructure and taxation on economic growth

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**Abstract**

This study is a contribution to the empirical literature that analyzes the effect of the core public infrastructure (telecommunication, electricity, and transportation) and indirect taxation on economic growth. We present empirical evidence through panel data analysis based on a comprehensive sample of countries (96) over a long period of time (1976 to 2011). The findings confirm the assumption that the core of public infrastructure is essential to promote economic growth. Furthermore, indirect taxation is not a tool capable of stimulating growth. In particular, new sectors of the core of public infrastructure, such as the internet and mobile telephony, are capable of expanding the effect of infrastructure on growth.

**Key words:** infrastructure; taxation, economic growth.

**JEL classification:** H54, H22, H30.

**Resumo**

Este estudo é uma contribuição para a literatura empírica que analisa o efeito do núcleo de infraestrutura pública (telecomunicações, eletricidade e transporte) e tributação indireta sobre o crescimento econômico. Apresentamos evidências empíricas através de análise de dados de painel com base em uma amostra abrangente de países (96) durante um longo período de tempo (1976 a 2011). As descobertas confirmam o pressuposto de que o núcleo da infraestrutura pública é essencial para promover o crescimento econômico. Além disso, a tributação indireta não é uma ferramenta capaz de estimular o crescimento. Em particular, novos setores do núcleo das infraestruturas públicas, como a internet e a telefonia móvel, são capazes de expandir o efeito da infraestrutura sobre o crescimento.

**Palavras-chave:** infraestrutura, tributação, crescimento econômico.

**Classificação JEL:** H54, H22, H30.

**Área 06: CRESCIMENTO, DESENVOLVIMENTO ECONÔMICO E INSTITUIÇÕES**

## 1. Introduction

Policymakers' decisions regarding infrastructure and taxation influence economic growth. An important issue for policymakers is whether government can boost economic growth through public policies that increase infrastructure. However, it is possible that an increase in taxation is necessary to enable the expansion of infrastructure, which can therefore counteract the expansion of the product. This paper makes an empirical investigation of the impact of the public infrastructure core (telecommunication, electricity, and transportation sectors) on economic growth and, in particular, whether indirect taxation is capable of eroding this effect.

The possible effect of infrastructure and taxation on economic growth relates to the Ricardian equivalence hypothesis. In an analysis for the USA, Blanchard and Perotti (2002) show that an increase in public spending leads to an increase in output while increasing taxation causes a reduction of output. Also in an analysis for the American economy, Barro and Redlick (2011) point out that productive public spending can promote economic growth, while taxation has a negative effect.

In general, the literature does not analyze the combined effect of public infrastructure and taxation on economic growth. In an analysis of the importance of infrastructure on growth for a sample of 75 countries, Esfahani and Ramírez (2003) note that the positive influence of infrastructure is greater than its generation cost. Regarding the effect of taxation, Prazmowski (2014) in an analysis for the Dominican Republic notes that an increase in public spending financed by an increase in the tax burden does not promote economic growth. In relation to the effect of public spending, Bleaney, Gemmell, and Kneller (1999) point out from a sample of 22 OECD countries that public spending associated with distortionary taxes have negligible or negative effects on growth.

This study is a contribution to the empirical literature that analyzes the effect of the core public infrastructure and indirect taxation on economic growth. The sectors that represent the core of public infrastructure (telecommunication, electricity, and transportation) are intrinsically related to productive capacity (Démurger, 2001; Agder, 2010; Calderón and Serven, 2010; Kunze, 2010; and Estache et al., 2013). Hence, an expansion of these sectors has the potential to promote growth. Although taxation may represent a source of resources for increasing infrastructure, the literature suggests that indirect taxation has a negative effect on growth (Cremer, Pestieau, and Rochet, 2001, Rivas, 2003, Smihan and Ozkan, 2010, Truyts, 2012, and Marattin, Marzo and Zagaglia, 2013). In addition, indirect taxation represents the main tax revenue, especially for developing countries (Peñalosa and Turnovsky, 2005).

In order to analyze the effect of core public infrastructure and indirect taxation on economic growth this study makes use of a comprehensive sample of countries (96) over a long period of time (1976 to 2011). Data are extracted from World Bank, Penn World Table 8.0 (PWT 8.0), and the OECD Starts. We present empirical evidence through panel data analysis (Fixed Effect - FE-OLS, and Method of Generalized Moments Systemic - S-GMM).

It is important to note that significant transformations have taken place in terms of public infrastructure since the early 1990s. The main changes observed are the increasing importance of mobile telephony and the internet (Gbaguiditi et al., 1999; Lam and Shiu, 2010 and Arvin et al., 2014). Information on the mobile telephony and internet sectors, as well as transportation sector (air and rail) for various countries became available from 1990 through the World Development Indicators (WDI). In this context, we introduce telecommunication (expanded with mobile telephony and internet) and transportation sectors (air and rail) in this study.

One characteristic of developing countries is the shortage of infrastructure and inefficiency in the use and tax collection (Reinikka and Svensson, 1999, and World Bank, 2008, Azzimonti, Sarte, and Soares, 2009, and Kerekes, 2012). Therefore, it is possible that the use of a subsample of developing countries shows results of the impact of public infrastructure and taxation on the economy that are different from those observed for the whole sample. Thus, this study presents empirical evidence for the case of developing countries through the IMF (63 countries) and World Bank (56 countries) rankings.

The findings confirm the hypothesis that the core of public infrastructure is fundamental to promote economic growth. In addition, indirect taxation is not a tool capable of stimulating growth. In particular, new sectors of the core of public infrastructure, such as the internet and mobile telephony, are capable of expanding the effect of infrastructure on growth.

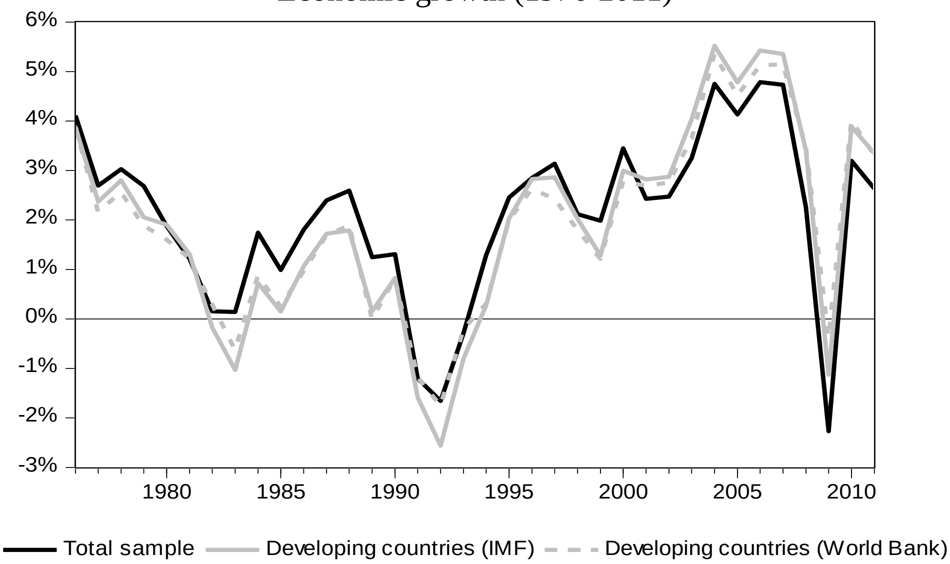
Besides this introduction, the article is organized as follows. The next section presents the data and methodology used in this study. Section 3 shows empirical evidence from a panel data analysis using FE-OLS and S-GMM methods. The last section presents the conclusion.

## 2. Data and methodology

In order to evaluate the impact of public infrastructure and taxation on economic growth, this study makes use of the panel data methodology for a sample of 96 countries for the period 1976 to 2011 (annual frequency - see table A1).[1] As in most of the literature, the dependent variable used in the models is the per capita real product growth rate (*Y*) extracted from PWT 8.0.[2] It is important to note that the set of countries used in the sample represents more than 94% of the real GDP of the world economy (PWT 8.0) and the 36 year period is adequate for analysis of economic growth.[3]

In order to observe if there is a distinction between the growth rates of the real per capita output of developing economies and the total sample in this study, figure 1 shows the average path of each sample for the period 1976-2011. The ratings made by the IMF and the World Bank do not show significant differences in the growth rates of developing countries. Furthermore, there is evidence that the growth rate of developing countries is higher than that observed for the total sample from the 2000s.

**Figure 1**
Economic growth (1976-2011)




The telecommunication, electricity, and transportation sectors represent the core

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[1] The period under consideration closes in 2011 due to unavailability of data for the infrastructure. Specifically, the series on "Electricity production – KWh" (indicator code: EG.ELC.PROD.KH) made available by the World Bank was closed in 2011 and the new series "% of total electricity output" (coal, hydroelectric, natural Gas, nuclear, oil, etc.) do not allow the updating of this information.

[2] Regarding the use of this variable as proxy for economic growth, see Barro (1991, 1995, 1996, 1997, 2003, and 2013), de Gregório (1993), Li and Liu (2005), Loayza and Ranciere (2006), Barro and Redlick (2011), Becker, Egger, and Von Ehrlich (2013), and Vinayagathasan (2013).

[3] For analysis on economic growth with similar span period, see Barro (1991 and 2003), De Gregógio (1993), and Li and Liu (2005).

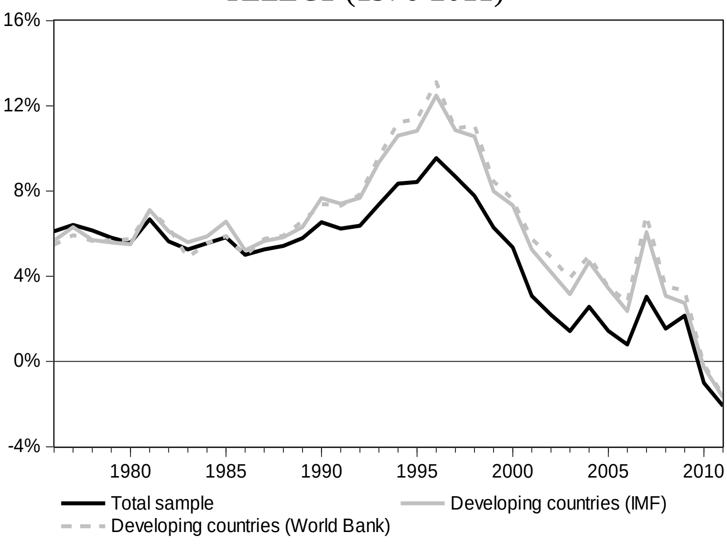
of public infrastructure and are the drivers of economic growth (World Bank, 1994; Agénor, 2010; Kunze, 2010; and Parikh et al., 2015). Based on the information available in the WDI and in the same way as Bougheas, Demetriades, and Mamuneas (2000) and Li and Liu (2005), the telecommunication sector (*TELEC1*) is the fixed telephony that corresponds to the growth rate of total telephone lines for the period 1976 to 2011. Since the 1990s, in addition to fixed telephony, mobile telephony and the internet have become relevant to the telecommunication sector (see Gbaguiditi et al., 1999). Hence, we built an indicator (*TELEC2*) for the period 1991-2011, which represents the weighted average of the growth rate of the main determinants of the telecommunication sector (fixed telephony, mobile telephony and internet).

In order to observe the evolution of the telecommunication sector over time, figure 2 shows the path (sample average) of the two indicators used in this study (*TELEC1* and *TELEC2*). *TELEC1* reveals that there has been a significant deceleration in the use of fixed telephony since 1996. Regarding *TELEC2*, after the strong expansion of the telecommunication sector in the second half of the 1990s there is a slowdown. Although the growth rate of the telecommunication sector measured by *TELEC2* fell due to the decline in the use of fixed telephony (see *TELEC1* path), the average growth rate for the last 5 years (independent of the sample) is higher than 10%. In addition, both *TELEC1* and *TELEC2* indicate that the growth rate of the telecommunication sector for developing countries is higher than that observed for the total sample since the late 1990s.

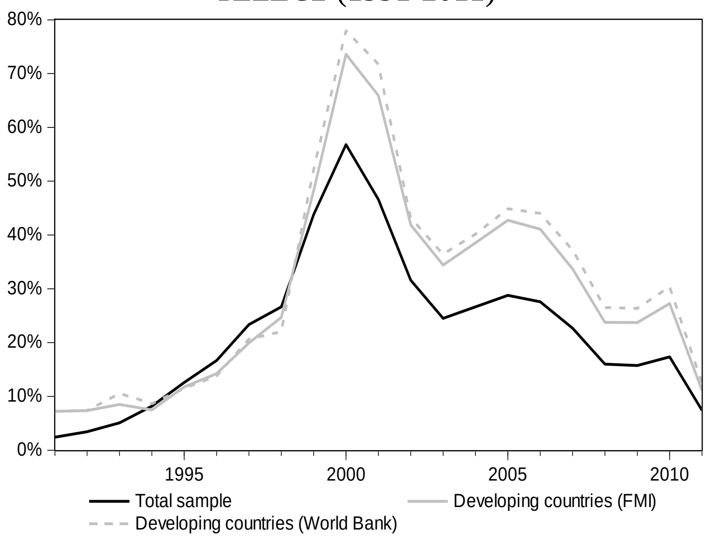
**Figure 2**

*Telecommunication sector (growth rate)*

*TELEC1* (1976-2011)



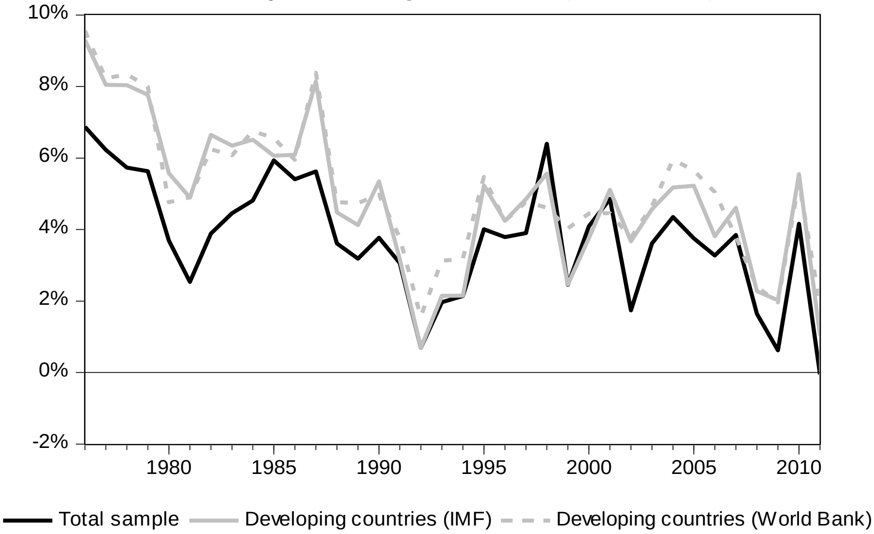

*TELEC2* (1991-2011)



Although most studies on economic growth neglects supply of electricity, it represents an essential source for the production of goods and services (Archibugi and Coco, 2004). Therefore, it is relevant to analyze the impact of the electric sector on growth. In order to introduce the electricity sector in this study, the growth rate of total production per kilowatt-hour (*ELECT)*, available from WDI, is considered. Figure 3 allows one to see that, independent of the sample, the electricity sector has presented a growth rate that has fluctuated close to 4% since the 1990s. Moreover, we can see that the growth rate of the electricity sector has been higher for developing countries.

**Figure 3**

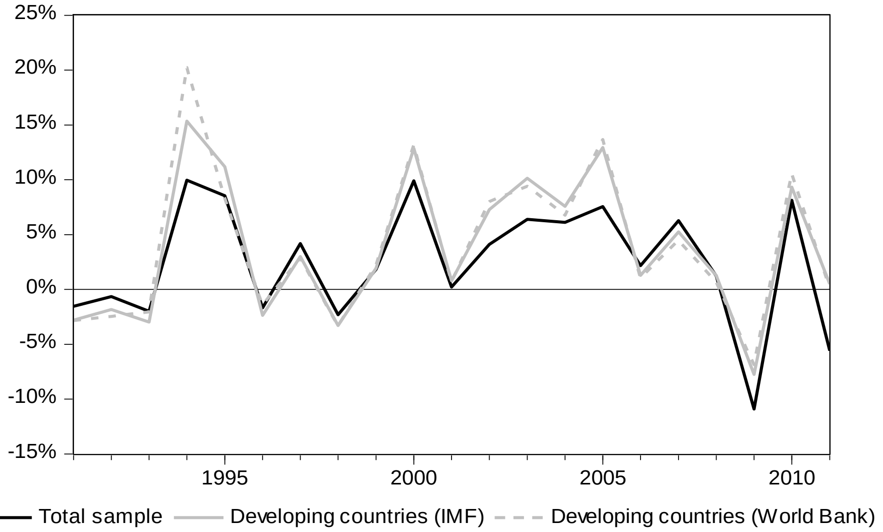
*Electricity sector – growth rate (1976-2011)*




According to Canning and Pedroni (2008), the transport sector has an important role in the analysis on economic growth. However, most of the literature disregards this sector because information for a significant number of countries is scarce. In order to fill this gap, this study considers information from two of the main representatives of the transportation sector: air and rail.[4] Based on the information available in the WDI, we built an indicator that corresponds to the weighted average of the growth rates of tonnage transported per useful kilometer for air and rail transportation (*TRANSP*). As can be seen from figure 4, independent of the sample, the transportation sector has a growth rate of around 5% most of the time. Moreover, in a different way from the other infrastructure sectors, there is no significant difference in the path for developing countries, when compared to the total sample.

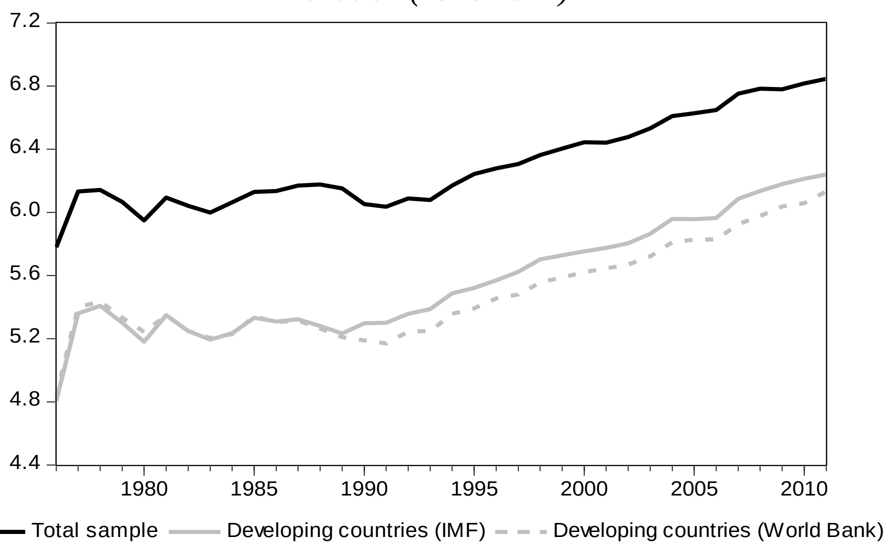
[4] Although road transport can be used as an infrastructure measure “the problem of producing consistent series seem almost insurmountable; the definition and coverage of the data vary too much over time and across countries” (Canning and Pedroni, 1998, 531).

**Figure 4**
*Transportation sector – growth rate (1976-2011)*




Several authors, such as Komendi and Meguire (1985), Rivas (2003), Ismihan and Ozkan (2010), and Barro and Redlick (2011) point out that taxation is a relevant variable to explain economic growth. In particular, they highlight that there is a negative effect of indirect taxation on income, employment, and consumption. Thus, in order to consider the effect of taxation (*TAX*) on growth, this study uses information extracted from the WDI and OECD Stats regarding real per capita taxation (US$ 2005=100). Figure 5 shows that there is a growth trend for taxation over time for all samples.

**Figure 5**
*Taxation (1976-2011)*




In addition to the aforementioned variables, we introduce into the model other variables that are traditional for the study of economic growth, thus the following variables are used (descriptive statistics are available in table A.1 - see appendix):

*INV* - Investment. From the information available in PWT 8.0, it corresponds to the logarithm of the ratio between the investment (2005 constant prices) divided by the population. The literature recognizes the variable investment as one of the main determinants of economic growth. See, Hoover and Perez (2004), Becker, Egger and Von Ehrlich (2013) and de Guimarães e Sousa, de Mendonça, and Andrade (2016).
*POP* - Population growth rate. Series obtained from the total population of PWT 8.0 (% per year). For examples of this use in the applied literature on economic growth see, Barro (2003), Mollick, Cabral, and Carneiro (2011) and, de Guimarães e Sousa, de Mendonça, and Andrade (2016).
*HC* - Human capital. Based on information extracted from PWT 8.0, it corresponds to the annual growth rate of human capital per capita, based on years of schooling (see, Barro and Lee, 2013) and returns to education (see, Psacharopoulos, 1994). For examples of use of this variable for applied economic growth analysis, see Chang, Kaltani, and Loayza (2009), and Ductor and Grechyna (2015).
*FDI* – Foreign direct investment. Based on the data available in the WDI, it refers to the logarithm of the ratio between net foreign direct investment (constant 2005 prices) and population. For examples of the use of this variable in applied economic growth analysis, see Bengoa and Sanchez-Robles (2003), Li and Liu (2005), and Guisan (2008).
*INF* - Inflation. Corresponds to the natural logarithm of the inflation rate measured by the CPI extracted from the WDI. Due to the presence of outliers, as suggested by Brito and Bystedt (2010), inflation in this study is a result of: $INF_t = log(1 + INF_t/100)$. For examples of the use of inflation rate in determining economic growth, see, Clark (1997), Brito and Bystedt (2010), and López-Villavicencio (2011).
*INST* - Political instability. From information extracted from the Center Systemic Peace, it is the result of armed conflicts, which occurred in episodes of international violence, civil violence, civil war, ethnic violence, and ethnic war involving the country in a given year. The magnitude of each conflict ranges from 0 (no conflict) to 10 (extermination and annihilation). For examples of the use of this variable for applied analysis of economic growth, see, Barro, (1991 and 2013) and Li and Liu (2005).

In order to observe the possible impact of public infrastructure and taxation on economic growth taking into account the variables mentioned above, the basic model is:

(1) $$Y_{i,t} = \gamma_1 Y_{i,t-1} + \gamma_2 TELEC1_{i,t} + \gamma_3 ELECT_{i,t} + \gamma_4 TAX_{i,t-1} + \gamma_5 X_{i,t} + \alpha_i + \mu_{i,t} \ ,$$

where $i$=1…N is the cross-section unit (countries); $t$=1…T is the time index; $\alpha$ allows for cross-country fixed effects; $X$ is a vector of explanatory variables (*INV*, *POP*, *HC*, *FDI*, *INF*, and *INST*); and $\mu$ is the stochastic error term.

In order to incorporate the changes that occurred with the telecommunication sector from the 1990s and to introduce the transportation sector in the analysis, we rewrite the previous model as follows:

(2) $$Y_{i,t} = \varphi_1 Y_{i,t-1} + \varphi_2 TELEC2_{i,t} + \varphi_3 ELECT_{i,t} + \varphi_4 TRANSP_{i,t} + \varphi_5 TAX_{i,t-1} + \varphi_6 X_{i,t} + \delta_i + \eta_{i,t} ,$$

where $\delta$ allows for cross-country fixed effects; and $\eta$ is the stochastic error term.

This study uses panel data analysis through models of fixed effect (FE-OLS) and System Generalized Method of Moments (S-GMM). The use of S-GMM is justified by the possibility of an endogeneity problem, which generally occurs due to omission of relevant variables, simultaneity, and measurement errors (Wooldridge, 2002). There is the possibility of occurrence of the three problems in this analysis. The reason is that it is impossible to know and measure all the variables that affect economic growth. Moreover, economic growth can influence the growth of infrastructure.

In order to treat the problem of endogeneity, Arellano and Bond (1991) indicated the use of the first difference of data and the use of lagged values of the endogenous variables as instruments in the models. However, Blundell and Bond (1998) showed that the first-difference GMM (D-GMM) has a bias (for large and small samples) and low accuracy. In order to improve the efficiency of GMM models, Arellano and Bover (1995) and Blundell and Bond (1998) recommend the addition of moment conditions. Hence, the suggestion is the combination of regression equations in differences and in levels into one system and uses lagged differences and lagged levels as instruments (S-GMM).

Although S-GMM estimation approach is suitable for a small number of time periods ($t$) and a large number of individuals ($i$), when the sample is small and when the instruments are too many they tend to over-fit the instrumented variables and bias the results (Roodman, 2009). Therefore, with the intention of avoiding the use of an excessive number of instruments in the regressions, the number of instruments/number of cross-sections is less than 1 in each regression (de Mendonça and Barcelos, 2015). Furthermore, as suggested by Arellano (2003), we perform the test of over-identifying restrictions (J-test) in order to confirm the validity of the instruments in the models and also tests of first-order (AR1) and second-order (AR2) serial correlation.

It is important to note that although we perform two-step GMM estimation, our sample is not the case for a small number of periods *t* (*t=36*) and it is not small relative to the number of countries (*i=96*). Therefore, there is not the risk of over-fitting the instrumented variables and biasing the results, thereby making the two-step system GMM estimator consistent (see Hayakawa, 2012).

## 3. Empirical evidence

As a way to observe the impact of public infrastructure and taxation on the economic growth, we estimate several panel data regressions. Taking into account the total sample, and *TELEC1* and *ELECT* sectors as infrastructure representatives, the next subsection presents empirical evidence from the FE-OLS and S-GMM methods. The following two subsections, based on the same framework, consider the sample of developing countries as classified by the IMF and the World Bank respectively. The fourth subsection extends the previous models through the insertion of new infrastructure sectors (*TELEC2* and *TRANSP*).

### 3.1. Total sample

Based on the models presented in section 2, this subsection presents the empirical results for the total sample, with 96 countries for the period 1976-2011. Independent of the method used, the results show that in all estimations the infrastructure variables (*TELEC1* and *ELECT*) have a positive impact on *Y*, whereas *TAX* has a negative and significant coefficient (see table 1). In particular, the fact that the coefficient *TELEC1* does not present statistical significance in all models suggests that fixed telephony may have diminished its importance for the production of wealth over time. In brief, the results are in agreement with the perspective that an increase in the infrastructure and a reduction in the taxation contribute to the increase of the economic growth. In general, all S-GMM regressions accept the null hypothesis in the Sargan tests (J-statistic) and thus the over-identifying restrictions are valid. Furthermore, both serial autocorrelation tests (AR(1) and AR(2)) do not indicate the presence of serial autocorrelation.

**Table 1**

*Estimations (full sample - 1976-2011)*

| Estimator/Regressors | FE-OLS | FE-OLS-CT | S-GMM |
|---|---|---|---|
| $Y_{i,t-1}$ | 0.2839*** | 0.2850*** | 0.2630*** |
| | (0.0355) | (0.0426) | (0.0502) |
| $TELEC1_{i,t}$ | 0.0106* | 0.0074 | 0.0030 |
| | (0.0060) | (0.0066) | (0.0026) |
| $ELECT_{i,t}$ | 0.0659*** | 0.0547*** | 0.1137*** |
| | (0.0144) | (0.0108) | (0.0278) |
| $TAX_{i,t-1}$ | -0.0082*** | -0.0071*** | -0.0596*** |
| | (0.0024) | (0.0021) | (0.0080) |
| $INV_{i,t}$ | 0.0111*** | 0.0133*** | 0.0218** |
| | (0.0031) | (0.0042) | (0.0081) |
| $POP_{i,t}$ | -0.8063*** | -0.8902*** | -1.1574*** |
| | (0.2423) | (0.2651) | (0.3931) |
| $HC_{i,t}$ | 0.2977** | 0.2786* | 1.9369** |
| | (0.1452) | (0.1631) | (0.7550) |
| $FDI_{i,t}$ | 0.0017** | 0.0020*** | 0.0075*** |
| | (0.0007) | (0.0007) | (0.0016) |
| $INF_{i,t}$ | -0.0234*** | -0.0251*** | -0.0411*** |
| | (0.0060) | (0.0061) | (0.0091) |
| $INST_{i,t}$ | -0.0024*** | -0.0026** | -0.0048*** |
| | (0.0009) | (0.0010) | (0.0013) |
| N. Obs. | 2394 | 2394 | 1937 |
| Adj. R² | 0.3825 | 0.4373 | |
| F-Statistic | 13.4998 | 14.3824 | |
| P-value | 0.0000 | 0.00000 | |
| N. Instruments/N. Cross Sections | | | 0.5000 |
| J-statistic | | | 35.4871 |
| P-value | | | 0.5862 |
| AR(1) | | | -0.4953 |
| P-value | | | 0.0000 |
| AR(2) | | | -0.0022 |
| P-value | | | 0.9933 |

Note: Marginal significance levels: (***) denotes 0.01, (**) denotes 0.05, and (*) denotes 0.1. White's heteroskedasticity consistent covariance matrix was applied in regressions. Standard errors between parentheses. FE-OLS – OLS fixed effects. FE-OLS-CT - OLS fixed effects with time period effects. S-GMM – uses two-step of Arellano and Bover (1995) without time period effects. Tests for AR (1) and AR (2) check for the presence of first order and second-order serial correlation in the first-difference residuals. The sample is an unbalanced panel of 96 countries from 1976 to 2011. Constant is included in FE-OLS and FE-OLS-CT models.

### 3.2. Developing countries

The models estimated in this subsection consider a sample of 63 developing countries according to the IMF classification and a sample of 56 developing countries according to the World Bank classification for the period 1976-2011 (see table 2) . The results for both samples (IMF and World Bank) indicate that considering only developing countries in the analysis does not alter the result for the total sample that both infrastructure and taxation are relevant for economic growth. In other words, the coefficients on *TELEC1* and *ELECT* are positive and the one referring to *TAX* is negative. Moreover, in the same way for the total sample, no statistical significance is observed for *TELEC1*.

**Tab le 2**

*Estimations – developing countries – IMF and World Bank classifications (1976-2011)*

| | Developing countries - IMF | | | Developing countries - World Bank | | |
|---|---|---|---|---|---|---|
| Estimator/Regressors | FE-OLS | FE-OLS-CT | S-GMM | FE-OLS | FE-OLS-CT | S-GMM |
| $Y_{i,t-1}$ | 0.2675*** | 0.2668*** | 0.0819*** | 0.2323*** | 0.2256*** | 0.1470*** |
| | (0.0429) | (0.0489) | (0.0222) | (0.0514) | (0.0567) | (0.0256) |
| $TELEC1_{i,t}$ | 0.0071 | 0.0054 | 0.0230 | 0.0062 | 0.0048 | 0.0032 |
| | (0.0045) | (0.0051) | (0.0200) | (0.0044) | (0.0049) | (0.0101) |
| $ELECT_{i,t}$ | 0.0618*** | 0.0568*** | 0.3516*** | 0.0629*** | 0.0569*** | 0.4340*** |
| | (0.0158) | (0.0127) | (0.0243) | (0.0182) | (0.0139) | (0.0364) |
| $TAX_{i,t-1}$ | -0.0075*** | -0.0071*** | -0.0287*** | -0.0073*** | -0.0071*** | -0.0132*** |
| | (0.0023) | (0.0022) | (0.0021) | (0.0022) | (0.0023) | (0.0025) |
| $INV_{i,t}$ | 0.0121*** | 0.0117** | 0.0178*** | 0.0149*** | 0.0149*** | 0.0075** |
| | (0.0035) | (0.0046) | (0.0034) | (0.0036) | (0.0044) | (0.0037) |
| $POP_{i,t}$ | -0.7057** | -0.5950 | -1.5459*** | -0.8469** | -0.7747* | -1.7165*** |
| | (0.3154) | (0.3862) | (0.1855) | (0.3335) | (0.4139) | (0.2028) |
| $HC_{i,t}$ | 0.3481* | 0.3957* | 0.9298*** | 0.3831* | 0.4396* | 1.1044*** |
| | (0.1898) | (0.2212) | (0.1340) | (0.2057) | (0.2540) | (0.1397) |
| $FDI_{i,t}$ | 0.0027*** | 0.0025** | 0.0080*** | 0.0017** | 0.0015 | 0.0047*** |
| | (0.0010) | (0.0010) | (0.0014) | (0.0008) | (0.0009) | (0.0011) |
| $INF_{i,t}$ | -0.0231*** | -0.0241*** | -0.0135*** | -0.0214*** | -0.0230*** | -0.0237*** |
| | (0.0062) | (0.0062) | (0.0027) | (0.0062) | (0.0062) | (0.0057) |
| $INST_{i,t}$ | -0.0022** | -0.0023** | -0.0028*** | -0.0029*** | -0.0030*** | -0.0014** |
| | (0.0010) | (0.0062) | (0.0019) | (0.0009) | (0.0011) | (0.0006) |
| N. Obs. | 1509 | 1509 | 1066 | 1365 | 1365 | 1057 |
| Adj. $R^2$ | 0.3580 | 0.4163 | | 0.3475 | 0.3966 | |
| F-Statistic | 12.6823 | 11.1497 | | 12.1759 | 10.0564 | |
| P-value | 0.0000 | 0.00000 | | 0.0000 | 0.00000 | |
| N. Instruments/N. Cross Sections | | | 0.8870 | | | 0.8392 |
| J-statistic | | | 48.9139 | | | 41.4779 |
| P-value | | | 0.3188 | | | 0.2817 |
| AR(1) | | | -0.4582 | | | -0.4400 |
| P-value | | | 0.0000 | | | 0.0000 |
| AR(2) | | | -0.0096 | | | -0.0397 |
| P-value | | | 0.7937 | | | 0.2467 |

Note: Marginal significance levels: (***) denotes 0.01, (**) denotes 0.05, and (*) denotes 0.1. White's heteroskedasticity consistent covariance matrix was applied in regressions. Standard errors between parentheses. FE-OLS – OLS fixed effects. FE-OLS-CT - OLS fixed effects with time period effects. S-GMM – uses two-step of Arellano and Bover (1995) without time period effects. Tests for AR (1) and AR (2) check for the presence of first order and second-order serial correlation in the first-difference residuals. The sample is an unbalanced panel of 63 countries from 1976 to 2011. Constant is included in FE-OLS and FE-OLS-CT models.

### 3.3. Sample increased by new telecommunication and transportation sectors

In order to consider the main transformations that occurred in the telecommunication and transportation sectors since the 1990s, this subsection presents regressions (S-GMM) from a sample of 74 countries for the period 1991-2011. Moreover, as a way of considering the specific case of developing countries, just as in the previous subsection the classifications made by the IMF and World Bank are used, which therefore implies a sub-sample of 46 and 40 countries respectively. In this context, this analysis is performed in two steps. The first step presents estimates (total and developing country samples) that considers the same variables that were used for the estimates for the period 1976-2011 (see table 3). The second step replaces the variable *TELEC1* with *TELEC2* (which considers fixed telephony, mobile telephony and the internet), and adds the transportation sector to the model (see table 4).

**Table 3**

*Estimations (1991-2011)*

| Regressors | Total sample | Developing countries - IMF | Developing countries -World Bank |
|---|---|---|---|
| $Y_{i,t-1}$ | 0.0963** | 0.1287** | 0.1459*** |
| | (0.0482) | (0.0537) | (0.0536) |
| $TELEC1_{i,t}$ | 0.0060 | 0.0228 | 0.0192 |
| | (0.0453) | (0.0531) | (0.0501) |
| $ELECT_{i,t}$ | 0.0894*** | 0.0747*** | 0.0720*** |
| | (0.0186) | (0.0200) | (0.0170) |
| $TAX_{i,t-1}$ | -0.1602*** | -0.1349*** | -0.1281*** |
| | (0.0180) | (0.0183) | (0.0190) |
| $INV_{i,t}$ | 0.0710*** | 0.0533*** | 0.0410*** |
| | (0.0133) | (0.0111) | (0.0130) |
| $POP_{i,t}$ | -2.3097*** | -1.4863** | -2.8123*** |
| | (0.7910) | (0.7194) | (0.8876) |
| $HC_{i,t}$ | 2.2244*** | 1.8082*** | 1.5691** |
| | (0.6687) | (0.6645) | (0.7232) |
| $FDI_{i,t}$ | 0.0202*** | 0.0273*** | 0.02286*** |
| | (0.0034) | (0.0046) | (0.0039) |
| $INF_{i,t}$ | -0.0605*** | -0.0459*** | -0.0424*** |
| | (0.0109) | (0.0090) | (0.0084) |
| $INST_{i,t}$ | -0.0120*** | -0.0135*** | -0.0137*** |
| | (0.0025) | (0.0032) | (0.0023) |
| N. Obs. | 957 | 615 | 523 |
| N. Instruments/N. Cross Sections | 0.5342 | 0.8000 | 0.9230 |
| J-statistic | 32.9683 | 30.8668 | 27.4552 |
| P-value | 0.2790 | 0.2332 | 0.3857 |
| AR(1) | -0.4123 | -0.4208 | -0.4443 |
| P-value | 0.0000 | 0.0000 | 0.0000 |
| AR(2) | -0.0314 | -0.0569 | -0.0521 |
| P-value | 0.4112 | 0.2207 | 0.3034 |

Note: Marginal significance levels: (***) denotes 0.01, (**) denotes 0.05, and (*) denotes 0.1. White's heteroskedasticity consistent covariance matrix was applied in regressions. Standard errors between parentheses. S-GMM – uses two-step of Arellano and Bover (1995) without time period effects. Tests for AR (1) and AR (2) check for the presence of first order and second-order serial correlation in the first-difference residuals. The sample is an unbalanced panel of 74 countries (total), 46 countries (developing - IMF), and 40 countries (developing - World Bank) from 1991 to 2011.

**Table 4**

*Estimations including TELEC2 and TRANSP (1991-2011)*

| | Total sample | | Developing countries - IMF | | Developing countries - World Bank | |
|---|---|---|---|---|---|---|
| Regressors: | Model 1 | Model 2 | Model 1 | Model 2 | Model 1 | Model 2 |
| $Y_{i,t-1}$ | 0.1855*** | 0.1945*** | 0.1364*** | 0.0750** | 0.1754*** | 0.1457*** |
| | (0.0208) | (0.0160) | (0.0443) | (0.0358) | (0.0298) | (0.0380) |
| $TELEC2_{i,t}$ | 0.0144*** | 0.0163*** | 0.0242*** | 0.0460*** | 0.0196*** | 0.0290*** |
| | (0.0008) | (0.0016) | (0.0071) | (0.0098) | (0.0043) | (0.0075) |
| $ELECT_{i,t}$ | 0.0942*** | 0.0784*** | 0.0808*** | 0.0450** | 0.0760*** | 0.0486*** |
| | (0.0097) | (0.0121) | (0.0243) | (0.0204) | (0.0216) | (0.0162) |
| $TRANSP_{i,t}$ | | 0.0269*** | | 0.1448*** | | 0.0929*** |
| | | (0.0047) | | (0.0164) | | (0.0184) |
| $TAX_{i,t-1}$ | -0.0674*** | -0.1021*** | -0.0653*** | -0.0646*** | -0.0586*** | -0.0589*** |
| | (0.0089) | (0.0092) | (0.0083) | (0.0082) | (0.0053) | (0.0063) |
| $INV_{i,t}$ | 0.0234*** | 0.0499*** | 0.0156** | 0.0285*** | 0.0139*** | 0.0350*** |
| | (0.0074) | (0.0064) | (0.0062) | (0.0066) | (0.0043) | (0.0063) |
| $POP_{i,t}$ | -0.6551** | -0.9358*** | -1.6997*** | -1.4784*** | -1.5939*** | -1.0902*** |
| | (0.2690) | (0.3211) | (0.6113) | (0.5111) | (0.4271) | (0.3549) |
| $HC_{i,t}$ | 0.3848** | 0.3920** | 1.3778*** | 1.4512*** | 1.0523*** | 1.3644*** |
| | (0.1803) | (0.1761) | (0.3321) | (0.3579) | (0.2501) | (0.3526) |
| $FDI_{i,t}$ | 0.0065*** | 0.0103*** | 0.0227*** | 0.0175*** | 0.0185*** | 0.0350*** |
| | (0.0014) | (0.0015) | (0.0023) | (0.0033) | (0.0017) | (0.0144) |
| $INF_{i,t}$ | -0.0300*** | -0.0281*** | -0.0240*** | -0.0655*** | -0.0273*** | -0.0158* |
| | (0.0101) | (0.0090) | (0.0062) | (0.0183) | (0.0046) | (0.0083) |
| $INST_{i,t}$ | -0.0041*** | -0.0074*** | -0.0058*** | -0.0053*** | -0.0059*** | -0.0070*** |
| | (0.0013) | (0.0017) | (0.0016) | (0.0019) | (0.0010) | (0.0010) |
| N. Obs. | 955 | 912 | 566 | 554 | 492 | 475 |
| N. Instruments/N. Cross Sectior | 0.7361 | 0.7361 | 0.8666 | 0.8636 | 0.9500 | 0.9473 |
| J-statistic | 46.3479 | 43.7932 | 31.7924 | 30.2403 | 31.1980 | 28.9196 |
| P-value | 0.3359 | 0.3953 | 0.3290 | 0.3034 | 0.3083 | 0.2672 |
| AR(1) | -0.3738 | -0.3908 | -0.3774 | -0.5569 | -0.4086 | -0.5444 |
| P-value | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| AR(2) | -0.0530 | -0.0395 | -0.0650 | -0.0023 | -0.0474 | -0.0133 |
| P-value | 0.1482 | 0.3167 | 0.1672 | 0.9685 | 0.3564 | 0.8287 |

Note: Marginal significance levels: (***) denotes 0.01, (**) denotes 0.05, and (*) denotes 0.1. White's heteroskedasticity consistent covariance matrix was applied in regressions. Standard errors between parentheses. S-GMM – uses two-step of Arellano and Bover (1995) without time period effects. Tests for AR (1) and AR (2) check for the presence of first order and second-order serial correlation in the first-difference residuals. The sample is an unbalanced panel of 74 countries (total), 46 countries (developing - IMF), and 40 countries (developing - World Bank) from 1991 to 2011.

The results in table 3 show that independent of the sample (total and developing countries) are consistent with those observed for the estimates with the total period of the sample (1976-2011). In other words, when considering only fixed telephony as a proxy for the telecommunication sector, the infrastructure that is significant for economic growth is the electricity sector. In addition, indirect taxation continues to be important in the model (coefficient on *TAX* is negative and significant).

The results from the substitution of *TELEC1* by *TELEC2*, and the inclusion of *TRANSP* in the model bring newness in relation to the previous estimates (see table 4). The coefficient on *TELEC2* is positive, and this observation indicates that add mobile telephony and the internet into the telecommunication sector contributes effectively to economic growth. The same observation is valid for the transportation sector (positive and significant coefficient). In the same way as observed in the estimates presented in the previous sections, indirect taxation has a negative and significant impact on growth in all models.

## 4. Concluding remarks

This paper analyzes the impact of infrastructure and indirect taxation on economic growth. With this objective, we presented several panel data estimations based on a total sample of 96 countries for the period 1976-2011. Furthermore, in order to include new infrastructure sectors into the analysis, and to verify changes since the 1990s, estimates are made for a total sample of 74 countries and their subsamples from developing countries for the period 1991-2011.

The evidence presented in this study shows that, as suggested by the literature, an increase in infrastructure and a reduction in taxation contribute to economic growth. However, to increase spending on public infrastructure a government needs a higher tax burden. In this sense, the results show that, in general, in developing economies, the positive impacts of infrastructure are able to overcome the negative effect of indirect taxation, which is the main source of these economies (see Peñalosa and Turnovsky, 2005). Moreover, the findings denote that the greatest impact of infrastructure on economic growth is in the case of developing countries. This fact confirms the assumption in the literature that in less developed economies greater infrastructure impacts on economic growth would be observed (see Azzimonti, Sarte, and Soares, 2009). In short, it is possible to verify that it is possible for policymakers to carry out public infrastructure expansion policies to achieve greater economic growth, even as a result of increased taxation, particularly in developing economies.

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# Appendix

**Table A.1**

Descriptive statistics

Total Sample (1976-2011)

| | $Y$ | $TELEC1$ | $ELECT$ | $TAX$ | $INV$ | $POP$ | $HC$ | $FDI$ | $INF$ | $INST$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.0208 | 0.0505 | 0.0413 | 6.3153 | 7.2401 | 0.0133 | 0.0082 | 4.4756 | 0.1511 | 0.7250 |
| Median | 0.0245 | 0.0355 | 0.0414 | 6.4089 | 7.4118 | 0.0129 | 0.0075 | 4.6869 | 0.0685 | 0.0000 |
| Maximum | 0.2926 | 1.2782 | 1.9213 | 8.8865 | 9.6366 | 0.0543 | 0.0604 | 10.7140 | 5.5017 | 13.0000 |
| Minimum | -0.4070 | -0.4590 | -1.0757 | -11.4522 | 2.0250 | -0.0397 | -0.0122 | -7.9720 | -0.0794 | 0.0000 |
| Standard deviation | 0.0481 | 0.1295 | 0.1005 | 1.4611 | 1.3120 | 0.0114 | 0.0069 | 2.1657 | 0.3457 | 1.7552 |
| N. Obs. | 3217 | 3352 | 3209 | 2850 | 3313 | 3317 | 3237 | 2858 | 3039 | 3320 |

Developing countries - IMF (1976-2011)

| | $Y$ | $TELEC1$ | $ELECT$ | $TAX$ | $INV$ | $POP$ | $HC$ | $FDI$ | $INF$ | $INST$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.0197 | 0.0635 | 0.0483 | 5.6121 | 6.5831 | 0.0165 | 0.0095 | 3.8212 | 0.1996 | 1.0299 |
| Median | 0.0251 | 0.0439 | 0.0529 | 5.7042 | 6.7775 | 0.0180 | 0.0091 | 4.1170 | 0.0889 | 0.0000 |
| Maximum | 0.2926 | 1.2782 | 1.9213 | 7.8230 | 8.9059 | 0.0543 | 0.0604 | 9.0680 | 5.5017 | 13.0000 |
| Minimum | -0.4070 | -0.4590 | -1.0757 | -11.4522 | 2.0250 | -0.0397 | -0.0122 | -7.9720 | -0.0794 | 0.0000 |
| Standard deviation | 0.0546 | 0.1543 | 0.1120 | 1.2167 | 1.1338 | 0.0119 | 0.0071 | 2.0628 | 0.4181 | 2.0569 |
| N. Obs. | 2089 | 2183 | 2051 | 1759 | 2101 | 2089 | 2089 | 1817 | 1892 | 2102 |

Developing countries - World Bank (1976-2011)

| | $Y$ | $TELEC1$ | $ELECT$ | $TAX$ | $INV$ | $POP$ | $HC$ | $FDI$ | $INF$ | $INST$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.0195 | 0.0657 | 0.0513 | 5.4936 | 6.4783 | 0.0180 | 0.0098 | 3.6265 | 0.1934 | 1.0880 |
| Median | 0.0245 | 0.0445 | 0.0544 | 5.6100 | 6.6695 | 0.0199 | 0.0094 | 3.9319 | 0.0896 | 0.0000 |
| Maximum | 0.2926 | 1.2782 | 1.9213 | 7.8230 | 8.8876 | 0.0543 | 0.0604 | 9.0680 | 5.5017 | 13.0000 |
| Minimum | -0.4070 | -0.4590 | -0.6888 | -11.4522 | 2.0250 | -0.0397 | -0.0122 | -7.9720 | -0.0794 | 0.0000 |
| Standard deviation | 0.0529 | 0.1622 | 0.1058 | 1.2472 | 1.1298 | 0.0113 | 0.0073 | 2.0652 | 0.4126 | 2.1173 |
| N. Obs. | 1897 | 1931 | 1859 | 1633 | 1953 | 1945 | 1897 | 1662 | 1735 | 1942 |

Total sample (1991-2011)

| | $Y$ | $TELEC1$ | $TELEC2$ | $ELECT$ | $TRANSP$ | $TAX$ | $INV$ | $POP$ | $HC$ | $FDI$ | $INF$ | $INST$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.0211 | 0.0399 | 0.2454 | 0.0292 | 0.0093 | 6.5306 | 7.4360 | 0.0095 | 0.0067 | 4.9943 | 0.1388 | 0.5702 |
| Median | 0.0263 | 0.0232 | 0.1448 | 0.0310 | 0.0115 | 6.8129 | 7.6603 | 0.0090 | 0.0051 | 5.3076 | 0.0439 | 0.0000 |
| Maximum | 0.1673 | 0.8738 | 8.1965 | 1.9213 | 5.5862 | 8.7372 | 9.5665 | 0.0543 | 0.0400 | 10.7140 | 5.5017 | 10.0000 |
| Minimum | -0.4070 | -0.4418 | -0.1403 | -1.0757 | -3.7739 | -11.4522 | 3.6547 | -0.0397 | -0.0086 | -6.5341 | -0.0458 | 0.0000 |
| Standard deviation | 0.0509 | 0.0959 | 0.4393 | 0.1083 | 0.3160 | 1.4331 | 1.2475 | 0.0105 | 0.0058 | 1.9226 | 0.3850 | 1.5107 |
| N. Obs. | 1614 | 1610 | 1303 | 1608 | 1490 | 1510 | 1628 | 1616 | 1616 | 1514 | 1563 | 1615 |

Developing countries - IMF (1991-2011)

| | $Y$ | $TELEC1$ | $TELEC2$ | $ELECT$ | $TRANSP$ | $TAX$ | $INV$ | $POP$ | $HC$ | $FDI$ | $INF$ | $INST$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.0227 | -0.0054 | 0.3396 | 0.0452 | 0.0079 | 5.7790 | 6.7360 | 0.0117 | 0.0077 | 4.2963 | 0.2005 | 0.8343 |
| Median | 0.0323 | -0.0022 | 0.2232 | 0.0455 | 0.0097 | 5.9307 | 6.9348 | 0.0127 | 0.0066 | 4.4896 | 0.0730 | 0.0000 |
| Maximum | 0.1673 | 0.0974 | 8.1965 | 5.8298 | 5.5862 | 7.8230 | 8.9059 | 0.0543 | 0.0296 | 9.0680 | 5.5017 | 10.0000 |
| Minimum | -0.4070 | -0.3866 | -0.1403 | -0.6589 | -3.7739 | -11.4522 | 3.6547 | -0.0397 | -0.0068 | -6.5341 | -0.0392 | 0.0000 |
| Standard deviation | 0.0592 | 0.0364 | 0.5506 | 0.2148 | 0.3893 | 1.2529 | 1.0539 | 0.0118 | 0.0059 | 1.8202 | 0.4749 | 1.8136 |
| N. Obs. | 1002 | 600 | 741 | 960 | 923 | 910 | 1012 | 1002 | 1002 | 955 | 963 | 1002 |

Developing countries - World Bank (1991-2011)

| | $Y$ | $TELEC1$ | $TELEC2$ | $ELECT$ | $TRANSP$ | $TAX$ | $INV$ | $POP$ | $HC$ | $FDI$ | $INF$ | $INST$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 0.0326 | 0.0576 | 0.3613 | 0.0501 | 0.0177 | 5.5940 | 6.6036 | 0.0134 | 0.0080 | 4.1210 | 0.1955 | 0.8831 |
| Median | 0.0349 | 0.0353 | 0.2293 | 0.0481 | 0.0133 | 5.6824 | 6.7504 | 0.0144 | 0.0075 | 4.3151 | 0.0732 | 0.0000 |
| Maximum | 0.1673 | 0.8738 | 8.1965 | 5.8298 | 3.4027 | 7.8230 | 8.8262 | 0.0543 | 0.0296 | 9.0680 | 5.5017 | 10.0000 |
| Minimum | -0.2268 | -0.4418 | -0.1403 | -0.4822 | -3.7739 | -11.4522 | 3.6547 | -0.0397 | -0.0068 | -6.5341 | -0.0392 | 0.0000 |
| Standard deviation | 0.0430 | 0.1189 | 0.5980 | 0.2209 | 0.3496 | 1.2340 | 1.0505 | 0.0114 | 0.0061 | 1.8283 | 0.4772 | 1.8800 |
| N. Obs. | 601 | 601 | 601 | 834 | 601 | 787 | 880 | 874 | 874 | 833 | 839 | 873 |