A new approach to test the effects of decentralization on public infrastructure investment

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ABSTRACT
This paper proposes a simple theoretical framework to obtain a tractable equation that considers the traditional criteria for allocating public infrastructure investment and variables to capture decentralization. Panel data for the regions of Spain over the period 1986–2010 are used. Positive effects of fiscal and administrative decentralization on public investment in infrastructure are found. The results are strongly robust to different relative measures of public infrastructure investment, estimation methods and databases. Moreover, in line with recent theoretical literature, additional estimations suggest that such effects are bounded and there is no long-run relationship between decentralization and public infrastructure investment.

KEYWORDS
decentralization; public infrastructure; Spain; panel data

JEL C23, H54, H77

INTRODUCTION

Scholars’ interest in the effects of decentralization on the economy has centred mainly on economic growth and the recent literature has suggested the existence of an optimal level of decentralization that maximizes the growth rate of the economy (Akai, Nishimura, & Sakata, 2007; Ogawa & Yakita, 2009; Thießen, 2003; Xie, Zou, & Davoodi, 1999), which can be interpreted as bounded effects of decentralization on the economy. Recently, interest has expanded on the effects of decentralization on the composition and efficiency of public expenditure, perhaps motivated by the theoretical results of Keen and Marchand (1997) who argued that in the case of uncoordinated fiscal competition, regions tend to over-invest in local public inputs to attract private capital, which has detrimental effects on welfare spending. However, this literature is still scarce. Kappeler and Väilälä (2008), Jia, Guo, and Zhang (2014) and Grisorio and Prota (2015a) showed evidence supporting the theoretical prediction of Keen and Marchand (1997). However, González-Alegre (2010) and Arze del Granado, Martínez-Vázquez, and McNab (2018) found no empirical support for such a theoretical prediction. Regarding efficiency, Balagué-Coll, Prior, and Tortosa-Ausina (2010), Boetti, Piacenza, and Turati (2012) and Brehm (2013) found that fiscal decentralization promotes allocative spending efficiency.

This paper studies the effect of decentralization on the provision of public infrastructure. Contributions in this strand of the literature are even more limited. In fact, the survey of the literature by Martínez-Vázquez, Lago-Peñas, and Sacchi (2017) shows scarce evidence on this topic. Recently, Kappeler, Solé-Ollé, Stephan, and Väilälä (2013) found a positive effect of revenue decentralization on the provision of infrastructure at the subnational level in 20 European countries, which is lower the higher the use of earmarked grants to fund infrastructure investment. A similar result was found by González-Alegre (2015) for the case of Spain. Therefore, this topic is interesting at the European level due to the regional policy of the European Union (EU) aims at narrowing the disparities between European regions by promoting the reduction of structural differences between regions of the EU.

Most of the literature mentioned above does not provide any theoretical framework to support the empirical implementation and considers only one measure of decentralization: revenue or expenditure decentralization (i.e., fiscal decentralization), despite the fact that a decentralization process might also involve the political and administrative dimensions. Moreover, most of the approaches propose linear relationships, which ignores the limited or bounded effects of decentralization on the economy, as pointed out by the recent literature. Considering a linear relationship implies assuming that the marginal
contribution of decentralization on the dependent variable is constant. That is, even though the decentralization process is almost complete, ceding the ‘last unit of decentralization’ would have the same marginal contribution on public infrastructure investment as the first one. This could be specially wrong in the case of variables capturing decentralization which, as most commonly assumed by the literature, are shares constrained in the interval [0, 1].

This paper aims at overcoming the shortcomings of the literature pointed out above when testing the effects of decentralization on public infrastructure investment. Thus, its contribution to the literature is threefold. First, the empirical methodology to achieve the paper’s objective is based on a theoretical framework that assumes that public infrastructure stock accumulates according to a non-linear function that allows for adjustment costs and/or diminishing returns of the investment in public infrastructure. Moreover, the public infrastructure stock is supposed to aim at catching up a ‘desired’ public infrastructure stock. Therefore, two equations must be simultaneously fulfilled in order to determine a function for the public infrastructure investment. Second, a non-linear specification is obtained, which allows one to test not only the signs of the effects but also decreasing marginal contributions of the variables capturing decentralization on public infrastructure investment (i.e., bounded effects). Furthermore, the resulting equation to be estimated embeds the traditional criteria for allocating public infrastructure investment. Third, this paper considers both revenues and expenditure decentralization and goes further by showing the effects of fiscal decentralization as well as casting evidence of the effects that administratively decentralized could have on the public infrastructure investment at the regional level.

The paper focuses on Spain, which is one of the most decentralized countries of Europe, alongside Switzerland, Germany and Belgium. All the autonomous communities (ACs), the Spanish regions, are considered with data over the period 1986–2010, and panel data estimation is applied. Equal political decentralization levels across regions was assumed since Spain’s transition from a centralized to a politically decentralized system of government occurred just after its transition towards democracy. From 1979 to 1983, all the regions of Spain were recognized as ACs and regional parliaments were created.

The empirical results show evidence of the positive effects of variables capturing decentralization on public infrastructure investment. However, in line with the recent theoretical literature, these effects seem to vanish provided the levels of decentralization increase over time. Moreover, additional empirical results show the nonexistence of a long-run relationship between decentralization and public infrastructure investment.

The objective of this paper is linked to the literature on the effects of decentralization on economic growth since several authors have introduced the stock of public infrastructure as an input of the production function (e.g., Aschauer, 1989). Therefore, if decentralization affects the allocation of public infrastructure investment, economic growth will also be affected.

However, the positive returns of the public infrastructure stock on the economy can by no means be taken for granted. The weak evidence found by Ford and Poret (1991) using data on Organisation for Economic Co-operation and Development (OECD) countries suggests that Aschauer’s results cannot be generalized to other countries. Moreover, the empirical implementation in Aschauer (1989) is considered to suffer from causality and endogeneity problems (Clarida, 1993; Gramlich, 1994). Furthermore, the early work by Hirschman (1958) already pointed out that investment in transport infrastructures can generate the so-called ‘leaking by linking’ phenomenon and bring gains and losses to regional economies, which has been supported by the literature on the ‘New Economic Geography’ (NEG). Moreover, Crescenzi and Rodriguez-Pose (2012) claimed that socioeconomic and institutional characteristics, which they called the ‘social filter’, play a key role. Interestingly, Flyvbjerg (2009) and Ansar, Flyvbjerg, Budzier, and Lunn (2016) found further evidence of the so-called ‘planning fallacy’ and stated that it results not only in delays but also in cost overruns, low revenues, debt and, in some cases, negative environmental and social impacts.

The paper is structured as follows. The theoretical framework is explained in the next section. The empirical strategy is presented in the third section, while the estimation issues are described in the fourth section. The fifth section shows the robustness checks; long-run dynamics are tested in the sixth section. Conclusions are drawn in the seventh section.

**THEORETICAL FRAMEWORK**

Let the public infrastructure stock per capita in region \(i\) in year \(t\), \(k_{it}\), accumulate according to the following law:

\[
k_{it} = \epsilon^{\delta} k_{it-1} \left( \frac{i_{it}}{s_{it}} \right)^{\delta},
\]

where \(i_{it}\) is the public infrastructure investment per capita in region \(i\) in year \(t\) and \(0 < \delta \leq 1\). A similar expression was used by Hercowitz and Sampson (1991), Kocherlakota and Yi (1997) and Cassou and Lansing (1998) to model the evolution of private capital stock. As pointed out by Cassou and Lansing (1998), the advantage of this specification with respect to the standard linear form is that equation (1) exhibits decreasing returns, which can be interpreted as reflecting adjustment costs in increasing the volume of public infrastructure stock or diminishing returns in the investment of public infrastructure. As assumed by Hercowitz and Sampson (1991), capital infrastructure accumulation is also subject to an exogenous shock, \(\epsilon^{\delta} > 0\), where \(\epsilon_{it}\) is a random disturbance with expected value, \(E(\epsilon_{it}) = 0\). According to Cassou and Lansing (1998), equation (1) might also be viewed as capturing the behaviour of an aggregate stock that is measured by adding up different types of capital which each display different depreciation characteristics. In the case of this paper, this assumption is very appropriate and is justified.
precisely because the public infrastructure stock is composed of several types of infrastructures such as highways, railways, airports, ports, etc.

Moreover, the planner aims at reaching a ‘desired’ stock of regional public infrastructure per capita, $k_{it}$, according to the following law:

$$k_{it} = e^{(Z_{it} + \xi_{it})} k_{it-1} \left( \frac{\hat{k}_{it}}{k_{it-1}} \right)^{\gamma}$$  (2)

The parameter $0 \leq \gamma \leq 1$ is the adjustment coefficient towards the desired stock and measures the strength of the catch-up effect; and $e^{(Z_{it} + \xi_{it})}$ is an exogenous shock that can deviate the planner from her objective. Thus, $Z_{it}$ is the deterministic part of the shock, with the expected value, $E(Z_{it}) = Z_{it}$, while $\xi_{it}$ is a random disturbance with the expected value, $E(\xi_{it}) = 0$. Notice that whenever $Z_{it} = 0$ and $\gamma = 1$ ($\gamma = 0$), the public infrastructure stock of a regional economy can only deviate from its desired (previous) level due to a random disturbance.

Consider that the objective is to achieve a level of public investment that simultaneously satisfies the two previous equations. Therefore, equalizing (1) and (2), the following is obtained:

$$i_{it} = \frac{e^{(Z_{it} + \xi_{it})}}{k_{it-1}} \left( \frac{\hat{k}_{it}}{k_{it-1}} \right)^{\gamma}$$  (3)

In this model the effects of decentralization accrue through $\hat{k}_{it}$.

According to the early theory of fiscal federalism (Mussgrave, 1959; Oates, 1972; Tiebout, 1956), higher tax and expenditure autonomy of subnational governments makes the provision of local public goods and services more efficient. Therefore, fiscal competition is expected to be growth enhancing to the extent that it increases public investment in public inputs (public infrastructure), which reduces production costs for private firms. Moreover, Keen and Marchand (1997) showed that fiscal competition among jurisdictions in a non-cooperative environment biases regional public spending in favour of local public inputs rather than consumption items. Based on this theory, empirical implementations often specify linear relationships and expect positive effects of variables capturing decentralization on the provision of public infrastructure.

**EMPIRICAL STRATEGY**

In the empirical implementation, $i_{it} = I_{it}/L_{it}$. It is considered ‘core infrastructure’ investment in constant euros with base year 2005, $I_{it}$, in region $i$ in year $t$. Gross investment, which includes new infrastructure and maintenance expenditures, is considered. The types of infrastructure included are roads and highways, hydraulic infrastructures, water systems, railways, airports and ports provided by all governments layers, public firms, autonomous entities and firms that privately provide public infrastructure. Any other urban infrastructures provided by local governments are also included. Data are from the BBVA Foundation and the Economic Research Institute of Valencia (Ivie). Table 1 shows the summary statistics of investment per capita by type of infrastructure and for each region. Investment in roads and highways has been the most prevalent, followed by railways. This can be explained by the orientation of economic policy since the 1980s to catch up with the main European countries. The third type of infrastructure that has received most investment is hydraulic infrastructures and water systems, since Spain is generally a dry country and infrastructures to store, distribute and reallocate water are needed to overcome the negative effects of drought.

It should be stressed that part of the annual aggregate regional investment has been funded by the European Structural and Investment Funds, especially through the Cohesion Funds. The management of such funds is the responsibility of the Spanish authorities, as stated in the partnership agreements on the European Structural and Investment Funds.

Population data per year in region $i, L_{it}$, are based on the Spanish National Bureau of Statistics (INE). $k_{it} = K_{it}/L_{it}$, where $K_{it}$ is the net public infrastructure stock in region $i$ in year $t$ including the same categories as above for public infrastructure investment. Data for $K_{it}$ are from the BBVA Foundation and Ivie. The methodology used to estimate $K_{it}$ was developed by Mas, Pérez, and Uriel (2015). It is based on the OECD methodology for the calculation of net capital stock following the perpetual inventory method, which allows estimating capital stock from the accumulation of past flows of gross fixed capital formation weighted by a combined age–price/retirement profile (OECD, 2009).

Typically, the literature considers only public infrastructure investment provided by regional and local governments. However, this paper focuses on total public infrastructure investment in region $i$ at time $t$ regardless of the provider. The reason to consider this is because, as pointed out by Oates (1972), fiscal competition results in a suboptimal level of provision of global public infrastructure and infrastructures that have spillover effects among regions. Hence, the role of the central government is crucial in warranting the provision of such infrastructures. Moreover, as pointed out by Kappeler et al. (2013), earmarked capital transfers often imply an increase in the capacity of the central government to intervene in the selection of investment projects; therefore, decisions are taken at the central level. Hence, it is considered that the variables capturing decentralization may affect not only the public infrastructure investment provided by the regional and local governments but also the public infrastructure provided by the central government and any other providers of public infrastructure. In fact, the levels of decentralization could be thought to give power to the regional governments in the bargaining process of making decisions regarding public infrastructure framed in national projects. Regions with more fiscal autonomy are believed to be more prone to complement central governments’ large investment projects. The construction of railways, ports and airports usually requires the urban transformation of cities, which...
Table 1. Summary statistics: public infrastructure investment per capita by type.

|                      | Roads and highways | Hydraulic and water systems | Railways | Airports | Ports | Others |
|----------------------|--------------------|-----------------------------|----------|----------|-------|--------|
|                      | Mean   | SD    | Mean   | SD     | Mean   | SD    | Mean   | SD    | Mean   | SD    | Mean   | SD    |
| Andalusia            | 188.8011 | 47.1083 | 85.1190 | 22.8525 | 68.3321 | 52.7810 | 16.0500 | 15.5860 | 21.7435 | 6.21803 | 45.9565 | 19.0706 |
| Aragon               | 289.1242 | 84.6227 | 148.1499 | 29.9241 | 185.3998 | 207.8628 | 5.9125 | 8.0904 | 0.0000 | 0.0000 | 76.7372 | 28.2198 |
| Asturias             | 316.0563 | 121.7316 | 104.5612 | 42.3536 | 85.4783 | 74.8615 | 3.8409 | 4.8712 | 60.3080 | 51.7240 | 57.2812 | 31.6895 |
| Balearic Islands     | 95.3858 | 23.0957 | 71.8274 | 21.8582 | 19.4701 | 33.9361 | 88.2058 | 48.5092 | 35.5464 | 12.9028 | 53.4756 | 20.6882 |
| Canary Islands       | 157.9074 | 67.6903 | 69.2511 | 16.7808 | 7.3282 | 12.0851 | 58.0689 | 19.7275 | 48.2030 | 10.7580 | 51.8625 | 20.5371 |
| Cantabria            | 369.6679 | 123.7658 | 91.7628 | 71.2730 | 34.7660 | 12.9823 | 5.7745 | 6.8697 | 42.2503 | 14.1059 | 59.7397 | 39.2708 |
| Castile and Leon     | 343.0862 | 95.5128 | 103.6729 | 21.6877 | 119.5938 | 115.0219 | 3.9744 | 5.7290 | 0.0000 | 0.0000 | 44.2868 | 16.9127 |
| Castile-La Mancha    | 331.2654 | 94.7403 | 98.8475 | 27.6459 | 160.0767 | 134.9645 | 8.9059 | 16.2751 | 0.0000 | 0.0000 | 42.1059 | 15.2280 |
| Catalonia            | 164.6579 | 49.2651 | 52.4462 | 17.8769 | 140.9516 | 130.0749 | 29.6920 | 28.2728 | 21.5537 | 7.4664 | 50.6990 | 22.9580 |
| Valencia             | 155.7734 | 42.2876 | 82.4321 | 19.0188 | 85.4068 | 51.8037 | 10.2971 | 12.1034 | 27.2103 | 9.4494 | 50.7032 | 19.8910 |
| Extremadura          | 270.1901 | 100.1434 | 185.1312 | 42.2430 | 28.4081 | 28.7082 | 0.4532 | 1.0402 | 0.0000 | 0.0000 | 21.8962 | 19.1622 |
| Galicia              | 260.2994 | 82.7327 | 61.2160 | 20.9910 | 81.0059 | 114.4937 | 8.3547 | 7.8587 | 41.5266 | 21.0376 | 19.8556 | 9.9044 |
| Madrid               | 102.4411 | 59.9780 | 46.5059 | 28.9981 | 153.4173 | 79.8684 | 69.8459 | 76.5626 | 0.0000 | 0.0000 | 65.3546 | 28.7440 |
| Murcia               | 161.4669 | 57.8616 | 133.4959 | 32.1031 | 21.0641 | 23.9696 | 3.0698 | 3.4960 | 19.0216 | 6.7446 | 51.0825 | 17.4110 |
| Navarre              | 268.0663 | 105.4101 | 117.9790 | 49.3099 | 15.1614 | 8.0318 | 5.5792 | 6.7541 | 0.0000 | 0.0000 | 69.8281 | 84.9685 |
| Basque Country       | 221.8707 | 58.9259 | 58.1238 | 23.5861 | 73.4491 | 36.9181 | 9.1956 | 7.5925 | 33.7284 | 10.9178 | 43.2989 | 29.3834 |
| La Rioja             | 215.9371 | 101.1335 | 97.5232 | 47.8121 | 14.9551 | 13.5206 | 5.1314 | 8.7999 | 20.2837 | 5.1918 | 49.4004 | 17.1497 |
| Spain                | 199.8183 | 40.9071 | 79.4102 | 11.5810 | 96.5914 | 61.0726 | 24.3704 | 15.8435 | 45.9565 | 19.0706 |

Note: SD, standard deviation.
is typically a task of regional governments. In such cases, both levels of government could get electoral returns. In addition, having more competencies can be associated with vindictive regions that claim increasing decision-making power, which can be used as a currency to obtain more investment from the central government. For instance, at the end of 2004, the Basque parliament approved a proposal for a new statute of autonomy that implied major changes in the relationship with the Spanish state (The Ibarretxe Plan). This proposal was eventually rejected by the central parliament in early 2005. However, in that year the public infrastructure investment per capita of the central government and other entities independent of the Basque government increased by 17.2% in the Basque Country, while the average in all Spain decreased by 3.5%. The ACs that reformed their statutes of autonomy in the period 2006–07, such as Valencia, Catalonia, Andalusia, Aragon and Castile–La Mancha, showed similar patterns.

**Specification of the evolution of the ‘desired’ stock of regional public infrastructure**

According to Castells and Solé-Ollé (2005), investment decisions are most likely based on the most recent data available for each region. This is a common assumption in the literature. Incidentally, it is very convenient for avoiding endogeneity problems in the estimation. Therefore, in order to estimate a model based on equation (3), $\hat{k}_{it}$ is specified as follows:

$$\hat{k}_{it} = (\phi_i + \xi^c_r) e^{y_{it-1}} \left( \frac{L_{it-1}}{S_i} \right)^{y_1} \left( \frac{e_{it-1}}{km_{it-1}} \right)^{y_2} FA_{it-1}^{*\epsilon_1} LA_{it-1}^{*\epsilon_2} NC_{it-1}^{*\epsilon_3},$$

(4)

where $\phi_i$ is a constant specific regional effect; and $\xi_r$ is a time effect. $y_{it-1}$ is the output per capita in region $i$ in period $t-1$. Gross added value per capita in constant euros with base year 2005 is used and was calculated with data from the INE. $L_{it-1}/S_i$ denotes population density in region $i$ in period $t-1$, and is intended to capture the effect of agglomeration. $e_{it-1}/km_{it-1}$ is the total number of vehicles per kilometres of roads in region $i$ in period $t-1$ and it allows the capture of the effect of congestion. Regional data on surface, vehicles and roads are taken from the INE.

Three explanatory variables are included to capture the effects of decentralization: $FA_{it-1}$ is the financial autonomy (share of ceded taxes and other own taxes and fees collected on total revenues excluding debt issuance). This variable was calculated as Aray (2018) using data provided by the Spanish Public Sector Database (Base de Datos del Sector Público Español – BADESPE). $LA_{it-1}$ is the ratio of the investment in public infrastructure per capita of the AC $i$ and its local governments to the public investment in infrastructure per capita of all ACs and theirs local governments of Spain in $t-1$. $NC_{it-1}$ is a variable that captures, in general, the decision-making power of the regions. As in Aray (2018), the royal decrees of transfers of competencies are used to proxy the number of competencies actually transferred to the regions. $NC_{it}$ is then constructed as in Aray (2018) with data that are from the Ministry of the Finance and Public Administrations (Ministerio de Hacienda y Administraciones Públicas). Thus, the variables $FA_{it-1}$ and $LA_{it-1}$ capture fiscal decentralization and the variable $NC_{it-1}$ captures administrative decentralization.

According to the literature supporting the positive effects of decentralization on public capital spending and the intuition that suggests that the marginal contribution of the above variables to the desired public infrastructure stock is not negative and not increasing, it could be expected that $0 \leq \varphi_j \leq 1$ for $j = 1, 2, 3, 4, 5, 6$.

**Equation to be estimated**

Let equation (4) be rewritten as follows:

$$\hat{k}_{it} = \hat{e}^{(\phi_i + \xi^c_r) y_{it-1} + \psi_1 (L_{it-1} / S_i) + \psi_2 (e_{it-1} / km_{it-1}) + \psi_3 FA_{it-1}^{*\epsilon_1} LA_{it-1}^{*\epsilon_2} NC_{it-1}^{*\epsilon_3}},$$

(5)

and define $Z_{it}$ as:

$$Z_{it} = \lambda_1 D_i + \lambda_2 E_i,$$

(6)

where $D_i$ is a dummy variable that collects partisan alignment (the same party holding office simultaneously in the central and regional government); and $E_i$ is a dummy variable for years in which regional electoral processes are held. $\lambda_1$ and $\lambda_2$ are parameters.

By substituting (5) and (6) into (3) and taking the natural logarithm, the equation to be estimated is obtained:

$$\log(\hat{k}_{it} / \hat{\kappa}_{it-1}) = \alpha_i + \tau_t + \theta_1 D_i + \theta_2 E_i$$

$$+ \beta_1 \log(\frac{y_{it-1}}{\hat{k}_{it-1}}),$$

(7)

$$+ \beta_2 \log(y_{it-1}) + \beta_3 \log(\frac{L_{it-1}}{S_i}) + \beta_4 \log(\frac{e_{it-1}}{km_{it-1}}),$$

$$+ \beta_5 \log(FA_{it-1}) + \beta_6 \log(LA_{it-1}) + \beta_7 \log(NC_{it-1}) + \mu_{it},$$

where $\alpha_i = \gamma \phi_i / \delta$ is the specific regional effect; $\tau_t = \gamma \xi_r / \delta$ is the time effect; and $\theta_1 = \lambda_1 / \delta$, $\theta_2 = \lambda_2 / \delta$, $\theta_1 = \gamma / \delta$, $\beta_2 = \gamma (\varphi_1 - 1) / \delta$, $\beta_j = \gamma \varphi_j / \delta$ for $j = 3, 4, 5, 6, 7$ and $\mu_{it} = (\xi_{it} - \varepsilon_{it}) / \delta$.

**Hypotheses**

Notice that the specification given by equation (7) allows one to control for the traditional criteria in the allocation of public investment: the efficiency and development criteria, special infrastructure needs and the political criterion.

The efficiency criterion is captured by $\log(y_{it-1} / \hat{k}_{it-1})$, which can be interpreted as a measure of the productivity of the public infrastructure stock. The model suggests that $\beta_1 \geq 0$.

The development or redistributive criterion is captured by $\log(y_{it-1})$. It should be expected that $\beta_2 \leq 0$ since it is
assumed that $0 \leq \varphi_1 \leq 1$. The redistribution criterion concerns positive discrimination towards lagging regions in order to foster the interregional convergence of production per capita.

The traditional trade-off between efficiency and redistribution is captured in specification (7), that is, to promote projects with a high economic impact and/or allocate infrastructure investment to reduce disparities. If highly productive regions benefit from public infrastructure investment, the national economy would be expected to grow faster, but probably at the cost of increased regional disparities. On the contrary, if the poorest regions are the beneficiaries, lower economic growth would be expected but with less disparities across regions.

Special infrastructure needs are captured by the variables agglomeration and congestion. Under this criterion, another dilemma arises. Targeting public infrastructure investment to reduce agglomeration and congestion costs with the objective of diminishing the negative externalities associated with urban expansion, hence $\beta_3 \geq 0$ and $\beta_4 \geq 0$. However, the regions with more severe symptoms of agglomeration and congestion typically have high levels of public infrastructure stock and it may be the case that the marginal returns of public infrastructure stock are lower than in the less agglomerated and congested regions, which have low levels of public infrastructure stock. Therefore, in terms of public infrastructure stock returns, targeting public investment in isolated and less densely populated regions would be desirable in order to improve accessibility and connect them with major urban centres, which suggests that $\beta_3 \leq 0$ and $\beta_4 \leq 0$. Hence, the expected signs of agglomeration and congestion turn out to be ambiguous.

The above trade-offs for allocating public infrastructure hold on further assumptions regarding the production function of the regions. It is assumed that the regional economy produces in $z$ according to a Cobb–Douglas production function whose inputs (private capital stock, labour, $N_{it}$, and public infrastructure stock, $K_{it}$) exhibit decreasing marginal returns and constant returns to scale in the private inputs as follows:

$$Y_{it} = A_{it}X_{it}^{\varphi_1}N_{it}^{1-\varphi_1}K_{it}^\rho, \quad \text{with } 0 < \alpha, \rho < 1$$

where the parameters of the production functions are assumed to be equal across regions; and $A_{it}$ is total factor productivity (TFP). Output per worker is then given by $\tilde{Y}_{it} = A_{it}x_{it}^{\rho}K_{it}^\rho$, where $x_{it}$ is the private capital stock per worker.

Consider two regions: region 1 (the rich) and region 2 (the poor). Should $A_{1t} = A_{2t}$ and $x_{1t} = x_{2t}$, the marginal return of the public infrastructure stock on output per worker will be larger in the region with lower (the poor) public infrastructure stock, since $K_{1t} > K_{2t}$. However, if $A_{1t} > A_{2t}$ and $x_{1t} > x_{2t}$, as is usually believed, in order for the poor region to have a larger marginal return of the public infrastructure stock than the rich one, the following condition must be fulfilled:

$$\left( \frac{K_{1t}}{K_{2t}} \right)^{1-\varphi_1} < \frac{A_{2t}}{A_{1t}} \left( \frac{x_{2t}}{x_{1t}} \right)^{\varphi_1}$$

Such simple theoretical conditions can be further explained following the suggestions of Crescenzi and Rodríguez-Pose (2012), who pointed out that the positive returns of infrastructure on the economy depend on a set of necessary conditions that shape the relationship between public infrastructure stock and the regional economies: innovation efforts and technology transfer and technical capabilities that, however, require an adequate ‘social filter’, which in this model is assumed to be captured by the TFP. The social filter allows one ‘to absorb new ideas and transform them into economically-useful knowledge’ (Crescenzi & Rodríguez-Pose, 2012, pp. 492–493), thus making the benefits of infrastructure investment more remarkable. Hence, Crescenzi and Rodriguez-Pose (2012) argued that any infrastructure investment aimed at boosting growth in a particular region needs to be assessed in light of the region’s own socioeconomic context as well as those of its neighbours.

The political criterion, as pointed out above, is captured by the dummies for partisan alignment and year of regional elections. According to the literature on distributive politics, it should be expected that $\alpha_1, \alpha_2 \geq 0$.

This paper goes further in adding the effects of decentralization by including the variables described above. According to the theoretical literature, these variables should have positive effects on the ratio of public infrastructure investment, that is, $\beta_5, \beta_6, \beta_7 \geq 0$.

### ESTIMATION ISSUES

Annual data over the period 1986–2010 are used. All the ACs of Spain (NUTS-2) are included. Table 2 shows summary statistics for the levels of the dependent variable and the explanatory variables. Significant heterogeneity across the Spanish regions are revealed in both the control variables and the variables of interest in this research. Panel A of Table 3 presents correlation coefficients among the explanatory variables. Special interest should be focused on the correlation coefficients among the variables capturing decentralization, which are low. Moreover, panel B shows that cross-sectional independence (Pesaran, 2004) is rejected for all variables at the 1% level of significance except for $\log(L_{4t-1})$ and $\log(N_{4t-1})$ whose cross-sectional independence hypotheses are rejected at the 5% and 10% levels, respectively.

Regressions were carried out with both fixed and random effects. The Hausman test ($H_{FE}$) provides evidence in favour of the fixed effect method. Therefore, Table 4 shows the results of the estimation of equation (7) with fixed effects. Standard errors robust to heteroskedasticity à la White (1980) and standard errors corrected for cross-sectional dependence à la Driscoll and Kraay (1998) are also provided, which are robust to very general forms of spatial and temporal dependence as the time dimension.
Table 2. Summary statistics of the variable used in the estimation.

| Region                | $\frac{I_t}{K_{t-1}}$ | Mean   | SD     | $\frac{y_{t-1}}{K_{t-1}}$ | Mean   | SD     | $y_{t-1}$ | Mean   | SD     | $\frac{I_{t-1}}{K}$ | Mean   | SD     |
|-----------------------|------------------------|--------|--------|---------------------------|--------|--------|-----------|--------|--------|---------------------|--------|--------|
| Andalusia             | 0.0702                 | 0.0274 | 1.9283 | 0.2938                    | 12,344.3600 | 2059.4110 | 25.5102 | 102.7261 | 3.8845             | 5.2052 |
| Aragon                | 0.0596                 | 0.0164 | 1.4536 | 0.1373                    | 17,304.1800 | 2960.3470 | 75.502  | 102.7261 | 3.8845             | 1.0513 |
| Asturias              | 0.0669                 | 0.0106 | 1.5502 | 0.3368                    | 14,157.1100 | 2211.7740 | 101.225 | 1.3711   | 1.3711             | 2.3648 |
| Balearic Islands      | 0.0668                 | 0.0122 | 3.6440 | 0.4477                    | 20,030.5600 | 1466.7560 | 166.5204 | 27.3648 | 27.3648             | 27.3648 |
| Canary Islands        | 0.0617                 | 0.0166 | 2.3403 | 0.2868                    | 15,324.6700 | 1491.5260 | 229.0311 | 1.6047   | 1.6047             | 1.6047 |
| Cantabria             | 0.0757                 | 0.0259 | 1.8883 | 0.4767                    | 15,395.7500 | 2249.2280 | 229.0311 | 1.3711   | 1.3711             | 2.3648 |
| Castile and Leon      | 0.0638                 | 0.0081 | 1.5489 | 0.2251                    | 13,150.4400 | 2062.0280 | 222.653 | 1.4072   | 1.4072             | 2.3648 |
| Castile-La Mancha     | 0.0719                 | 0.0238 | 1.4177 | 0.2122                    | 13,150.4400 | 2062.0280 | 222.653 | 1.4072   | 1.4072             | 2.3648 |
| Catalonia             | 0.0697                 | 0.0171 | 3.0048 | 0.3380                    | 19,480.7000 | 3001.4860 | 199.376 | 15.3722  | 15.3722             | 15.3722 |
| Valencia              | 0.0674                 | 0.0145 | 2.4168 | 0.3596                    | 15,199.0500 | 2034.6990 | 181.258 | 17.8587  | 17.8587             | 17.8587 |
| Extremadura           | 0.0642                 | 0.0214 | 1.2553 | 0.1547                    | 10,352.3000 | 2318.3240 | 93.1700 | 0.7035  | 0.7035             | 0.7035 |
| Galicia               | 0.0730                 | 0.0147 | 2.0977 | 0.4659                    | 13,123.2300 | 2318.3240 | 93.1700 | 0.7035  | 0.7035             | 0.7035 |
| Madrid                | 0.0766                 | 0.0215 | 3.8929 | 0.7159                    | 21,562.8400 | 3460.7800 | 662.9818 | 63.1901 | 63.1901             | 63.1901 |
| Murcia                | 0.0690                 | 0.0190 | 2.4376 | 0.3548                    | 14,123.2300 | 2318.3240 | 93.1700 | 0.7035  | 0.7035             | 0.7035 |
| Navarre               | 0.0510                 | 0.0153 | 2.1514 | 0.1656                    | 20,528.0500 | 2981.2790 | 52.6333 | 3.9182  | 3.9182             | 3.9182 |
| Basque Country        | 0.0546                 | 0.0142 | 2.3730 | 0.2788                    | 19,744.9100 | 3526.2000 | 293.0116 | 2.9768  | 2.9768             | 2.9768 |
| La Rioja              | 0.0375                 | 0.0099 | 1.5768 | 0.1846                    | 17,610.7600 | 3079.7810 | 54.8694 | 3.9718  | 3.9718             | 3.9718 |

Notes:
- $\frac{I_t}{K_{t-1}}$: Public infrastructure investment per capita as a ratio of the stock of public infrastructure per capita in the previous period.
- $\frac{y_{t-1}}{K_{t-1}}$: Gross added value per unit of public infrastructure.
- $y_{t-1}$: Gross added value per capita.
- $\frac{K_{t-1}}{L_{t}}$: Population density.
- $\frac{K_{t-1}}{N_{t}}$: Vehicles/km of road.
- $FA_{t-1}$: Financial autonomy.
- $IA_{t-1}$: Investment autonomy.
- $NC_{t-1}$: Proxy for the decision-making power.
- SD, standard deviation.
Table 3. Correlation coefficients across explanatory variables and cross-sectional independence test.

(A) Correlation coefficients across explanatory variables

|                      | log \((\frac{y_{i,t-1}}{x_{i,t-1}})\) | log \(y_{i,t-1}\) | log \((\frac{\text{Lit}_{t-1}}{\text{Si}_{t-1}})\) | log \((\frac{\text{cit}_{t-1}}{\text{kmit}_{t-1}})\) | log \((\frac{\text{FA}_{i,t-1}}{\text{IA}_{i,t-1}})\) | log \((\frac{\text{NC}_{i,t-1}}{\text{IA}_{i,t-1}})\) |
|----------------------|---------------------------------|-----------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| log \((\frac{y_{i,t-1}}{x_{i,t-1}})\) | 1.0000                         |                 |                                  |                                  |                                  |                                  |
| log \(y_{i,t-1}\)    | 0.3201                         | 1.0000          |                                  |                                  |                                  |                                  |
| log \((\frac{y_{i,t-1}}{x_{i,t-1}})\) | 0.7574                         | 0.4466          | 1.0000                          |                                  |                                  |                                  |
| log \((\frac{\text{Lit}_{t-1}}{\text{Si}_{t-1}})\) | 0.6983                         | 0.5860          | 0.9166                          | 1.0000                          |                                  |                                  |
| log \((\frac{\text{FA}_{i,t-1}}{\text{IA}_{i,t-1}})\) | 0.1252                         | 0.7468          | 0.2434                          | 0.3180                          | 1.0000                          |                                  |
| log \((\frac{\text{NC}_{i,t-1}}{\text{IA}_{i,t-1}})\) | -0.3934                        | -0.0740         | -0.3891                         | -0.4689                         | 0.0990                          | 1.0000                          |
| log \((\frac{\text{FA}_{i,t-1}}{\text{IA}_{i,t-1}})\) | 0.1574                         | -0.2258         | 0.2383                          | 0.2130                          | -0.3242                         | -0.0840                         |
| log \((\frac{\text{NC}_{i,t-1}}{\text{IA}_{i,t-1}})\) | -1.69                          | 0.0920          |                                  |                                  |                                  |                                  |

(B) Cross-sectional independence test

|                      | CD test          | p-value          |
|----------------------|------------------|------------------|
| log \((\frac{y_{i,t-1}}{x_{i,t-1}})\) | 18.96            | 0.0000           |
| log \((\frac{y_{i,t-1}}{x_{i,t-1}})\) | 37.54            | 0.0000           |
| log \((\frac{y_{i,t-1}}{x_{i,t-1}})\) | 54.32            | 0.0000           |
| log \((\frac{y_{i,t-1}}{x_{i,t-1}})\) | 32.97            | 0.0000           |
| log \((\frac{\text{Lit}_{t-1}}{\text{Si}_{t-1}})\) | 56.59            | 0.0000           |
| log \((\frac{\text{FA}_{i,t-1}}{\text{IA}_{i,t-1}})\) | 39.11            | 0.0000           |
| log \((\frac{\text{FA}_{i,t-1}}{\text{IA}_{i,t-1}})\) | -2.41            | 0.0160           |
| log \((\frac{\text{NC}_{i,t-1}}{\text{IA}_{i,t-1}})\) | -1.69            | 0.0920           |

A new approach to test the effects of decentralization on public infrastructure investment.
becomes large. This is particularly convenient for the approach adopted here of considering total regional investment, since several regions might be involved in many large national investment projects (e.g., a new railway line, roads). Furthermore, standard errors robust to spatial dependence allow one to account for the effects of decentralization of a particular region and its resultant policies on neighbouring regions, and vice versa.9

Notice that equation (7) might still suffer from an endogeneity problem caused by the variable \( \log(y_{it-1}/k_{it-1}) \). Therefore, the exogeneity tests of Hausman and Davidson and MacKinnon are provided in Table 4, which do not suggest that the variable \( \log(y_{it-1}/k_{it-1}) \) is endogenous and the Sargan test validates the use of the instruments.10

Table 4. Panel data regression of equation (7) with fixed effects.

| Coefficient | Ordinary least squares (OLS) SE | White SE | Driscoll-Kraay SE |
|-------------|---------------------------------|----------|------------------|
| \( D_i \)   | 0.0322                          | 0.0217   | 0.0345           | 0.0233           |
| \( E_k \)   | 0.0068                          | 0.0303   | 0.0230           | 0.0182           |
| \( \log(\frac{k_{it}}{k_{it-1}}) \) | 0.9383                          | 0.1395***| 0.1559***        | 0.1788***        |
| \( \log(y_{it-1}) \) | -1.3921                         | 0.4050***| 0.5380**         | 0.4151***        |
| \( \log(\frac{k_{it}}{k_{it-1}}) \) | -1.4468                         | 0.3471***| 0.4489***        | 0.3909***        |
| \( \log\left(\frac{y_{it}}{y_{it-1}}\right) \) | -0.0544                         | 0.2359   | 0.4477           | 0.2737           |
| \( \log(FA_{it-1}) \) | 0.1580                          | 0.0298***| 0.0330***        | 0.0265***        |
| \( \log(A_{it-1}) \)   | 0.1317                          | 0.0362***| 0.0517**         | 0.0460**         |
| \( \log(NC_{it-1}) \)   | 0.8438                          | 0.1488***| 0.2371***        | 0.2278***        |
| \( R^2 \)             | 0.5284                          |          |                  |                  |

| Test            | Coefficient | Standard Error |
|------------------|-------------|----------------|
| \( H_{HB} \)     | 24.80       | 0.0032         |
| \( H^*_{HB}; \beta_1 = 1 \) | 0.20       | (0.6587)       |
| \( H_{HB}; \beta_1 = 1, \beta_2 = 1 \) | 436.93    | (0.0000)       |
| \( H_{HB}; \beta_1 = 1, \beta_2 = 1 \) | 311.08    | (0.0000)       |
| \( H_{HB}; \beta_1 = 1, \beta_2 = 0 \) | 0.68      | (0.5083)       |
| \( H_{HB}; \beta_1 = 1, \beta_2 = 1 \) | 16.45     | (0.0000)       |
| \( H_{HB}; \beta_1 = 1, \beta_2 = 0 \) | 7.84      | (0.0005)       |
| \( H_{HB}; \beta_1 = 1, \beta_2 = 1 \) | 16.08     | (0.0000)       |
| Hausman test     | 7.53 (0.5821) |            |
| Davidson–Mackinnon test | 0.04 (0.8411) |                  |
| Sargan test      | 0.17 (0.6821) |            |

Notes: SE, standard error.
***, **, *Significant at 1%, 5% and 10% levels, respectively.

The result suggests that public infrastructure investment policy in Spain has aimed to promote interregional convergence in per capita production in order to reduce regional disparities.

The coefficients of the variables that reflect the special infrastructure needs show negative effects of agglomeration and congestion. The first is significant at the 1% level in all cases, while congestion is not significant at any conventional level, which could be explained by the high correlation with population density. In general, the results regarding special infrastructure needs might be related to the argument in favour of reducing the isolation of regions with a lower population density, which are typically those with less congestion. Thus, such regions have benefited from investment in infrastructure to be incorporated or connected to the main development hubs. This is one of the common criticisms of large Spanish public investment projects in isolated areas that appear to have little economic and social justification, which are somehow suggested as examples of the ‘planning fallacy’. This literature has found evidence showing that the best projects are not necessarily implemented, but rather those that look best on paper, which typically have the largest cost underestimates and benefit overestimates and usually undervalue negative environmental and social impacts.
The results regarding efficiency and development criteria and infrastructure needs somehow suggest that the aggregate investment in public infrastructure aims to overcome the dilemma between efficiency, equity and isolation through a balanced distribution of public infrastructure investment across the Spanish regions.

In relation to the political criterion, although estimates show the expected signs, no evidence was found.

As for the variables of interest in this research, all variables that capture the effects of decentralization have significant positive coefficients at the 1% level in most of the estimations. Therefore, as expected, more independence in the collection and management of revenues and investment allocation (fiscal decentralization) as well as greater decision-making power (administrative decentralization) contribute to the increase in the public infrastructure investment ratio of the ACs.

This result is in line with the early works on fiscal federalism theory and the scarce empirical literature testing the effects of fiscal decentralization on public infrastructure investment.

This paper goes further by providing, for the first time, evidence of the effects of administrative decentralization on public infrastructure investment. Nevertheless, evidence of administrative decentralization on economic growth had already been provided by Filippetti and Sacchi (2016) who found that administrative and political decentralization conditions the positive effect of fiscal decentralization on economic growth. However, Rodríguez-Pose and Ezcurra (2011) and Aray (2018) found a weak negative effect of administrative decentralization on economic growth. Moreover, as shown in the survey by Martínez-Vázquez et al. (2017), studies that test the effects of administrative and political decentralization tend to focus on socioeconomic variables such as well-being (Bjørnskov, Drehe, & Fischer, 2008), income inequality and poverty (Rodríguez-Pose & Ezcurra, 2010; Tselios, Rodríguez-Pose, Pike, Tomaney, & Torrisi, 2012), and corruption (Dell’Anno & Teobaldelli, 2015; Lederman, Loayza, & Soares, 2005).

The positive effect of fiscal decentralization can be interpreted as is usually done in the literature, since it has to do with the power to manage resources, while the positive effect of administrative decentralization in Spain could be related to the development and evolution of the regions’ statutes of autonomy. Furthermore, the results could suggest, in general, that the more resource autonomy and more competencies transferred, the greater the regional bargaining power with the central government to attract investments in public infrastructure.

Policy implications point to the strengthening of the decentralization process in Spain if the objective is to increase the regional public infrastructure stock, which is assumed to foster economic growth and reduce regional disparities as stated in the EU regional policy objectives.

However, caution should be taken given the theoretical contributions that warn about the coordination failures that could arise under decentralization as well as the criticism of the excess optimism of the empirical results of Aschauer (1989) and the negative consequences of the ‘planning fallacy’. Moreover, according to the NEG literature, decreasing interregional transport costs, largely due to public infrastructure investment, prompts firms and workers to agglomerate into the core region, which increases spatial differences in production between the core and periphery. Accordingly, Puga (2002) concluded that despite large regional policy expenditures funded by the EU, inequalities between regions within each member state have increased. Nevertheless, the theoretical result of Martin and Rogers (1995) sheds a light on this issue by highlighting the positive effects of improvements in local infrastructure on the peripheral regions, which could offset the harmful effects of interregional infrastructure. In this sense, greater decision-making power, along with regional planners’ supposedly better awareness of local needs, could be helpful in putting forward and choosing the best projects in order to counteract the negative externalities due to agglomeration economies.

One of the drawbacks of equation (7) is that the initial parameters \(\delta, \gamma, \phi_1, \zeta, \) and \(\varphi, j = 1, 2, 3, 4, 5, 6 \) are unidentified. However, the hypothesis \(H^5: \beta_1 = 1 \) can be tested, which suggests that \(\delta = \gamma \) and, hence, \(\alpha_i = \phi_j, \tau_i = \zeta_i, \beta_2 = \varphi_1 - 1 \) and \(\beta_j = \varphi_j \) for \(j = 3, 4, 5, 6, 7 \). Table 4 shows that this hypothesis is not rejected.

In order to test for linear relationships between the decentralization variables and the dependent variable, the joint hypotheses \(\beta_1 = 1 \) and \(\beta_5 = 0 \), \(\beta_1 = 1 \) and \(\beta_6 = 0 \), and \(\beta_1 = 1 \) and \(\beta_7 = 0 \) were tested and rejected, while the hypothesis \(\beta_1 = 1 \) and \(\beta_7 = 0 \) was not rejected. Additionally, the joint hypotheses \(\beta_1 = 1 \) and \(\beta_5 = 0 \), \(\beta_1 = 1 \) and \(\beta_6 = 0 \), and \(\beta_1 = 1 \) and \(\beta_7 = 0 \) were tested and rejected. These results suggest that \(0 < \varphi_1 < \varphi_2 < 1 \) and \(\varphi_3 < 1 \). Hence, a non-linear relationship is found for fiscal decentralization and the public infrastructure investment ratio, while it is linear related to administrative decentralization. The results hold in all the estimations carried out and are available from the author upon request.

Finally, note that the model exhibits a high explanatory power since it can explain about 53% of the variability in the log of public infrastructure investment ratio (\(R^2 = 0.5284 \)). Appendix A in the supplemental data online shows estimations by types of public investment.

**ROBUSTNESS CHECKS**

**Variables measured per worker**

Models of economic growth usually measure variables per worker. This section shows the results of estimating equation (7) with the variables measured per worker and efficient worker (human capital) instead of per capita.\(^{11}\)

Table 5 shows the results with robust standard errors à la Driscoll and Kray (1998), which hardly vary.

**Estimation considering the route taken towards autonomy**

Three types of ACs can be distinguished in the decentralization process in Spain depending on the route they took towards autonomy. Some took the routes established in
Articles 143 and 151 of the Spanish Constitution, while others are the so-called foral communities. As pointed out by Molero (2001) and Carrión-i-Silvestre, Espasa, and Mora (2008), the ACs that took the Article 143 route have carried out slower decentralization processes. The main difference between the communities that took the Article 143 route and the formal communities is that the latter were granted full financial autonomy. In this subsection, equation (7) is estimated assuming different coefficients for type of ACs as classified above for the variables that capture decentralization.

Table 6 shows the results of the estimation with robust standard errors à la Driscoll and Kraay (1998) and for the three cases considered: variables measured per capita, per worker and per efficient worker. As can be noticed, the results for the control variables remain similar in the three cases. As for the variables of interest, it is shown that the results are robust to any of the measures used. More interestingly, the evidence is stronger for the communities that took the Article 151 route, followed by the foral communities, while for the communities that took the Article 143 route evidence was only found for financial autonomy. The results for financial autonomy could be suggesting the existence of a bound. Notice that the coefficient is significant for communities that took either routes 143 or 151, while for the foral communities, which have full financial autonomy, it is not significant.

Table 6 also shows the results of the null hypotheses of equal coefficients across the types of ACs. Thus, $H^{ED}$ tests the hypothesis that the coefficients of the variable that captures financial autonomy are equal across the types of ACs defined above. A similar interpretation applies to $H^{LD}$ and $H^{NC}$. As can be seen, $H^{ED}$ and $H^{NC}$ are not rejected in all cases, while $H^{LD}$ is only rejected at the 10% level of significance. Therefore, there seems to be evidence in favour of the model of equation (7) with equal coefficients across ACs.

**An alternative database: BD.MORES**

The BD.MORES regional database is used to carry out many regional analyses and reports published as working papers by the Spanish Ministry of Finance and Public Administration. Although BD.MORES is not an official database, its characteristics are interesting for Spanish regional-level research because it uses one base year in order to ensure the homogeneity of several macroeconomic variables. The last version was released in December 2015 and takes 2008 as the base year.

The BD.MORES variables used to estimate equation (7) were public investment infrastructure ($I_v$), public infrastructure stock ($K_v$), gross added value ($Y_v$), population ($L_v$), and number of workers ($N_v$). The results with robust standard errors à la Driscoll and Kraay (1998) are shown in Table 7, which are very similar to the previous ones shown in Tables 4 and 5.

**LONG-RUN DYNAMICS**

Based on the literature that suggests that the effects of decentralization on economic growth are limited, it is considered that decentralization could also have bounded effects on the provision of public infrastructure. In fact, this is already captured in the non-linear specification proposed in this paper. However, such a specification assumes that elasticities are constant over the full period. In order to provide stronger evidence, this section follows the proposal of Aray (2018) of splitting the full sample period into three sub-periods. The key years are 1993 and 2001, since major reforms in the Spanish financing system of the ACs were...
### Table 6. Panel data regression of equation (7) with fixed effects and considering the route taken to the autonomy.

| Variables per worker | Coefficient | SE  | Coefficient | SE  | Coefficient | SE  |
|----------------------|-------------|-----|-------------|-----|-------------|-----|
| $D_t$                | 0.0159      | 0.0254 | 0.0186      | 0.0263 | 0.0204      | 0.0262 |
| $E_t$                | 0.0014      | 0.0193 | −0.0001     | 0.0189 | 0.0010      | 0.0194 |

$$ \begin{align*} 
\log \left( \frac{y_{it}}{y_{it-1}} \right) & = 0.9204 \pm 0.1741*** \\
\log(y_{it-1}) & = -1.4079 \pm 0.4464*** \\
\log \left( \frac{\left( \frac{y_{it}}{y_{it-1}} \right)}{\left( \frac{y_{it-1}}{y_{it-2}} \right)} \right) & = -1.3099 \pm 0.4353*** \\
\log \left( \frac{\left( \frac{y_{it}}{y_{it-1}} \right)}{\left( \frac{y_{it-1}}{y_{it-2}} \right)} \right) & = -0.0529 \pm 0.2522 \\
\log(FA_{it-1}) & = 0.1512 \pm 0.0247*** \\
\log(IA_{it-1}) & = 0.0762 \pm 0.0465 \\
\log(NC_{it-1}) & = 0.6172 \pm 0.3972 \\
\log(FA_{143}) & = 0.1529 \pm 0.0532** \\
\log(IA_{143}) & = 0.2343 \pm 0.0638*** \\
\log(NC_{143}) & = 1.3505 \pm 0.2472*** \\
\log(FA_{foral}) & = -0.1007 \pm 0.4721 \\
\log(IA_{foral}) & = 0.2648 \pm 0.1116** \\
\log(NC_{foral}) & = 0.6151 \pm 0.2653** \\
\end{align*} $$

Notes: SE, standard error.
***, **, *Significant at 1%, 5% and 10% levels, respectively.

### Table 7. Panel data regression of equation (7) with fixed effects and using the BD.MORES database.

| Variables per capita | Coefficient | SE  | Coefficient | SE  |
|----------------------|-------------|-----|-------------|-----|
| $D_t$                | 0.0194      | 0.0271 | 0.0186      | 0.0263 |
| $E_t$                | −0.0010     | 0.0198 | −0.0032     | 0.0206 |

$$ \begin{align*} 
\log \left( \frac{y_{it}}{y_{it-1}} \right) & = 1.0400 \pm 0.2640*** \\
\log(y_{it-1}) & = -1.3741 \pm 0.5537*** \\
\log \left( \frac{\left( \frac{y_{it}}{y_{it-1}} \right)}{\left( \frac{y_{it-1}}{y_{it-2}} \right)} \right) & = -1.2886 \pm 0.5111** \\
\log \left( \frac{\left( \frac{y_{it}}{y_{it-1}} \right)}{\left( \frac{y_{it-1}}{y_{it-2}} \right)} \right) & = -0.1104 \pm 0.2384 \\
\log(FA_{it-1}) & = 0.0977 \pm 0.0361** \\
\log(IA_{it-1}) & = 0.1219 \pm 0.0429** \\
\log(NC_{it-1}) & = 0.6724 \pm 0.2228*** \\
\end{align*} $$

Notes: SE, standard error.
***, **, *Significant at 1%, 5% and 10% levels, respectively.
carried out in these years and are therefore suspected to have caused structural breaks.

Table 8 shows the results. As can be seen, in general, the results for the control variables across periods remain similar to Table 4. The variables capturing decentralization are mostly significant in the two first periods. However, they are not significant at any conventional level in the last period, which could be related to the high level of decentralization achieved by the regions of Spain. Therefore, these results are in line with the above literature that posits bounded effects of decentralization on the economic growth. In fact, a kind of hump-shaped relationship

|                  | 1986–93 | 1994–2001 | 2002–10 |
|------------------|---------|-----------|---------|
|                  | Estimates | Driscoll–Kraay SE | Estimates | Driscoll–Kraay SE | Estimates | Driscoll–Kraay SE |
| \(D_t\)          | −0.0586 | 0.0228**  | −0.0670 | 0.0389         | 0.0115 | 0.0251         |
| \(E_t\)          | 0.0369 | 0.0142**  | −0.0370 | 0.0228         | 0.0491 | 0.0350         |
| \(\log\left(\frac{L_{it}}{L_{i-1}}\right)\) | 0.9505 | 0.2844*** | 0.9897 | 0.6550         | 1.0472 | 0.4938**       |
| \(\log(y_{it-1})\) | −1.6548 | 0.5632*** | −1.8623 | 0.9848*        | −1.1802 | 0.6286*        |
| \(\log\left(\frac{L_{it}}{L_{i-1}}\right)\) | −3.1212 | 0.3966*** | −2.6099 | 0.8202**       | −1.6593 | 0.5607***      |
| \(\log\left(\frac{L_{it}}{L_{i-1}}\right)\) | −0.4739 | 0.2725     | 1.3484  | 0.1883***      | 2.2769  | 0.6517***      |
| \(\log(FA_{it-1})\) | 0.0730 | 0.0251**  | 0.1074  | 0.0611*        | 0.0643  | 0.0458         |
| \(\log(IA_{it-1})\) | 0.1418 | 0.0832     | 0.2231  | 0.0795**       | −0.0120 | 0.0468         |
| \(\log(NC_{it-1})\) | 1.0037 | 0.4562**  | 0.3691  | 0.1218***      | 0.0752  | 0.3889         |
| \(R^2\)          | 0.5919 | 0.3849     | 0.3413  | 0.3413         |         |                |
| \(\mu^{\alpha}\) | 0.03 (0.8641) | 0.00 (0.9876) | 0.01 (0.9250) |          | 0.01 (0.9250) |                |

Notes: SE, standard error.
***, **, *Significant at 1%, 5% and 10% levels, respectively.

Table 8. Panel data regression of equation (7) with fixed effects across subsample periods.

(A) Pesaran’s CADF test

|                  | Levels | First differences |
|------------------|--------|-------------------|
|                  | Without trend | With trend | Without trend | With trend |
|                  | \(Z_{t-[bar]}\) | \(p\)-value | \(Z_{t-[bar]}\) | \(p\)-value | \(Z_{t-[bar]}\) | \(p\)-value | \(Z_{t-[bar]}\) | \(p\)-value |
| \(\log\left(\frac{L_{it}}{L_{i-1}}\right)\) | −0.48 | 0.3160 | −0.16 | 0.4350 | −7.21 | 0.0000 | −5.86 | 0.0000 |
| \(\log(FA_{it-1})\) | 0.65 | 0.7420 | 2.22 | 0.9870 | −7.02 | 0.0000 | −5.47 | 0.0000 |
| \(\log(y_{it-1})\) | −0.42 | 0.3370 | 4.10 | 1.0000 | −7.22 | 0.0000 | −7.28 | 0.0000 |
| \(\log(\frac{L_{it}}{L_{i-1}})\) | 1.91 | 0.9720 | 0.59 | 0.7230 | −3.39 | 0.0000 | −2.07 | 0.0190 |
| \(\log(\frac{L_{it}}{L_{i-1}})\) | 1.90 | 0.9710 | 4.15 | 1.0000 | −5.37 | 0.0000 | −4.43 | 0.0000 |
| \(\log(FA_{it-1})\) | −1.48 | 0.0700 | 0.80 | 0.7880 | −6.07 | 0.0000 | −4.03 | 0.0000 |
| \(\log(IA_{it-1})\) | −0.08 | 0.4670 | −0.01 | 0.4960 | −7.52 | 0.0000 | −5.43 | 0.0000 |
| \(\log(NC_{it-1})\) | −1.94 | 0.0260 | −6.54 | 0.0000 | −6.15 | 0.0000 | −3.58 | 0.0000 |

Note: Two lags were used for variables in level, and one lag for variables in first difference.

(B) Westerlund ECM-based cointegration test between decentralization and public infrastructure investment ratio

|                  | Value | Z-value | \(p\)-value | Robust \(p\)-value |
|------------------|-------|---------|--------------|-------------------|
| \(G_t\)         | −2.31 | 1.87    | 0.9690       | 0.3400           |
| \(G_a\)         | −2.22 | 6.83    | 1.0000       | 0.8900           |
| \(P_t\)         | −4.42 | 6.09    | 1.0000       | 0.9300           |
| \(P_a\)         | −1.74 | 5.65    | 1.0000       | 0.9000           |
between the variables capturing fiscal decentralization and the public infrastructure investment ratio across the periods is suggested.

Alternatively, it is tested whether there is a long-run relationship between the dependent variable and the variables capturing decentralization. The methodology proposed by Grisorio and Prota (2015b) is followed. The second generation panel unit root test proposed by Pesaran (2007), which allows for cross-section dependence, is performed. Panel A of Table 9 shows that all variables are non-stationary, except \( \log(NC_{it-1}) \). However, they are stationary in first differences. The next step is to check for a cointegration relationship between \( \log(i_{it}/k_{it-1}) \) and the log of the variables capturing decentralization using the error correction based cointegration test developed by Westerlund (2007). Panel B of Table 9 shows that none of the tests proposed by Westerlund (2007) rejects the null hypothesis of no cointegration at any conventional level. Therefore, there does not seem to be a long-run relationship between decentralization and the public infrastructure investment ratio, which is in line with the literature that suggests a bounded effect of decentralization on the economy.

CONCLUSIONS

This paper tests the effects of decentralization on the ratio of public infrastructure investment to public infrastructure stock in the previous year for the regions of Spain over the period 1986–2010. A theoretical framework is proposed so that a tractable equation for the empirical strategy can be obtained. Specifically, an equation that allows one to control for traditional criteria to allocate public infrastructure investment is estimated. The empirical results show that fiscal and administrative decentralization positively affect investment allocation in public infrastructure. Moreover, the results could suggest that decentralization seems to provide the regions greater bargaining power with the central government in order to attract more public infrastructure. In line with the recent theoretical literature, additional results cast evidence of the limited effects of decentralization on public infrastructure investment. This finding is further supported by providing a cointegration test that suggests that there is no long-run relationship between decentralization and public infrastructure investment.

The results are strongly robust to different measures of public investment infrastructure, estimation methods and databases.

Several issues should be considered in future research when analyzing the effects of decentralization on public infrastructure provision. One interesting issue concerns the last idea discussed in this research regarding the limited effects of decentralization on public infrastructure investment. In fact, alternative approaches could be considered to provide new insight on such bounded effects. For instance, models considering regimes could be useful in providing evidence on this topic conditioned on determined economic characteristics of the regions.

Moreover, studies showing evidence of vertical and horizontal coordination among government layers for providing public infrastructure could be useful to test the theoretical result of Keen and Marchand (1997). In this regard, cooperation across subnational layers of government and the aligning of incentives for the provision of infrastructure is an issue of major interest that merits consideration.

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NOTES

1. According to the World Bank’s definition, administrative decentralization places planning and implementation responsibilities in the hands of elected local governments.
2. For a survey of the effects of public capital on the economy, see Bom and Ligthart (2014).
3. In 1996, the law was modified to make public–private partnerships (PPP) more flexible. In 2003, Act 13/2003 of 23 May extended the PPP for any kind of public infrastructure, allowing private initiative to undertake activities required to design, build, finance and operate (DBFO). It also regulated the distribution of risk between grantor and concessionaire, rates and concession time. Act 30/2007 of 30 October repelled Act 13/2003, but hardly modified the PPP (Vassallo Magro & Izquierdo de Bartolomé, 2010). Road and highways are the type of infrastructure where PPP is most common.
4. The data for Spain are currently included in the Structural Analysis database (STAN) and the Productivity database, both of the OECD and EU KLEMS.
5. It includes items 102, 103, 202, 203 and 600 of the public investment series of the BBVA Foundation–Ivie.
6. These variables were constructed based upon RULERS, World Statesmen.org and the Spanish Ministry of Home Affairs (Ministerio del Interior).
7. Rich (1989) summarizes the earlier prominent theories in the literature of distributive politics.
8. The autonomous cities of Ceuta and Melilla are not considered here owing to the lack of data for the entire period.
9. However, the estimations and testing of interregional spillover and network effects are beyond the scope of this paper. For more on this, see González-Alegre (2015).
10. The results of the two-stage least squares (2SLS) estimation are similar to Table 4. These are available from the author upon request.
11. Data come from the Bancaja Foundation–Ivie.
12. These include Aragon, Asturias, the Balearic Islands, Cantabria, Castile–La Mancha, Castile–Leon, Extremadura, La Rioja, Madrid and Murcia.
13. These include Andalusia, the Canary Islands, Catalonia, Valencia and Galicia.
14. The Basque Country and Navarre are formal communities. Formally, they also took the route of Article 151. However, because of their particular characteristics, they are usually classified in a different category.
15. Estimation across types of autonomous communities was also carried out and similar results to Table 6 were obtained. These are available from the author upon request.

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