Infrastructure Investment and Spanish Economic Growth, 1850-1935*

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Abstract

This paper analyzes the impact of infrastructure investment on Spanish economic growth between 1850 and 1935. Using new infrastructure data and VAR techniques, this paper shows that the growth impact of local-scope infrastructure investment was positive, but returns to investment in large nation-wide networks were not significantly different from zero. Two complementary explanations are suggested for the last result. On the one hand, public intervention and the application of non-efficiency investment criteria were very intense in large network construction. On the other hand, returns to new investment in large networks might have decreased dramatically once the basic links were constructed.

Keywords: Infrastructure, Networks, Railroads, Economic Growth, Cointegration, VAR, Industrialization, Spain

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1. Introduction

This paper explores the economic effects of infrastructure investment during the first stages of Spanish industrialization. Despite abundant research on the topic, there is no agreement among historians on the impact that increases in the stock of infrastructure had on late nineteenth and early twentieth century Spanish economic growth. Research on the subject has focused to a large extent on the railroad system, which accounted for the highest share of infrastructure investment at the time, and which has been seen, alternatively, as either one of the "heroes" of Spanish industrialization or one of the explanatory factors for the country's economic underperformance.

Tortella (1973) set the basis of the pessimistic view. He pointed out that Spanish railroads were constructed ahead of demand and, as a consequence, railroad companies faced a situation of excess capacity that made them unprofitable during most of their lives. To make things worse, the construction of the Spanish railroads had very small "backward linkages", since imports of the necessary materials were given generous tariff exemptions that deprived the Spanish iron industry of a crucial source of demand. Later on, however, Gómez Mendoza (1983) suggested a much more positive interpretation on the subject. He stressed the importance of the transport cost-saving effect of the Spanish railroad system. According to this author, the social savings of the Spanish railroads and their effects on economic growth were much larger than in other European countries due, among other reasons, to the lack of opportunities for the development of inland waterways in Spain.

Subsequently, historians have raised several *caveats* about Gómez Mendoza's optimistic interpretation. On the one hand, Tortella (1999, p. 250) and Comín *et al.*

(1998, 1, pp. 140-141) have indicated that, despite the social saving evidence, the low density of use and the lack of profitability of the Spanish railroads constitute powerful proofs of their economic failure. On the other hand, further research has provided substantially lower estimates of the social savings of the Spanish railroads in the late nineteenth century (Barquín, 1999; Herranz-Loncán, 2002). However, at the same time, Herranz-Loncán (2005a) has pointed out that the social savings do not capture all the impact of the railroads, due to the difficulty to measure TFP spillovers. These might have been quite relevant in Spain, where nineteenth century market integration provoked a substantial change in the geography of economic activity (Tirado *et al.*, 2002; Rosés, 2003; Pons *et al.*, forthcoming), as well as the gradual convergence in living standards across Spain (Rosés and Sánchez-Alonso, 2004). In summary, the economic impact of the Spanish railroads is still the object of an open debate, in which no agreement has been reached among researchers so far.

This paper re-addresses the question of the growth impact of Spanish infrastructure investment during the late nineteenth and early twentieth century from a different viewpoint. Instead of focusing on railroads, as most previous research, it adopts an aggregate perspective that takes into account the whole infrastructure sector. Using a new data set of Spanish infrastructure for the period 1845-1935 and the most recent estimates of Spanish output and capital formation, I estimate a vector autoregressive (VAR) system that allows analyzing the relationship between infrastructure investment and economic growth. The VAR framework has often been used to measure the growth impact of infrastructure in present economies (Clarida, 1993; McMillin and Smith, 1994; Otto and Voss, 1996; Pereira and Andraz, 2005). Among other advantages, this technique allows accounting for the non-stationarity of time-series data and for the presence of mutual causation and indirect relationships among different variables. In addition, VAR methods are especially appropriate in the case of historical research, in which the paucity of quantitative information prevents from using more sophisticated techniques (e.g. Groote *et al.*, 1999).

This paper describes how, in a preliminary analysis, the VAR approach seems to indicate that Spanish infrastructure investment did not have any significant long or short-term impact on productivity between 1850 and 1935. Previous papers that found infrastructure increases not to have any positive effects on productivity growth are, among others, Tatom (1991), Holtz-Eakin (1994), McMillin and Smith (1994), Baltagi and Pinnoi (1995), Balmaseda (1996) and Garcia-Milà *et al.* (1996). However, all these works analyze mature high-income economies, for which the available evidence on potential infrastructure shortages is inconclusive (Gramlich, 1994; Fernald, 1999). The absence of productivity effects of infrastructure is more difficult to find and interpret in industrializing countries in which the most basic infrastructure is being built. Groote *et al.* (1999), for instance, have observed a clear positive short-to-medium term reaction of Dutch GDP to infrastructure increases between 1853 and 1913.

The outcomes of the VAR analysis may be better understood when Spanish infrastructure investment is disaggregated into two categories: local-scope infrastructure and large nation-wide transport and communication networks. In this case, the estimation results show that the former had an unmistakable positive impact on productivity and the apparent lack of growth effects of infrastructure in the aggregate analysis was actually driven by the latter. These results may be explained on the basis of the differences between both infrastructure categories. Unlike local-scope infrastructure, nation-wide transport and communication systems were characterized by two distinct features. Firstly, government intervention and non-efficiency allocation criteria were very influential in the investment decisions, and reduced the returns to some of the resources invested. And, secondly, large systems were characterized by decreasing returns to network expansion. As a consequence, although the construction of the basic network links probably provoked substantial changes in the economy, returns to additional investment were rather low. This paper provides therefore some possible explanations for other historical cases or for present LDC in which the effect of infrastructure on output appear to be muted in econometric analyses.

The paper is organized as follows. Section 2 describes the infrastructure dataset that has been used in the estimation and offers a brief summary of the process of infrastructure construction in Spain between the central years of the nineteenth century and the eve of the Civil War of 1936-1939. Section 3 presents the model that has been used to analyze the relationship between infrastructure and economic growth, and the main estimation results. In Section 4, I discuss some possible explanations for the lack of response of Spanish productivity to investment in transport and communication networks. Section 5 concludes.

2. Infrastructure investment in Spain, 1845-1935

Most econometric analyses of the growth impact of infrastructure investment use public capital figures as a proxy for infrastructure. This procedure might be justified to some extent in the case of present economies (Gramlich, 1994, p. 1177), but it would have been misleading for late nineteenth and early twentieth century Spain, where a large number of assets, such as railroads, tramways, the telephone system, power distribution networks and some hydraulic works (i.e., more than 50 per cent of the infrastructure stock) were privately owned. Instead, this paper is based on a recent estimation of Spanish infrastructure investment between 1845 and the Civil War, which includes not only information about public capital formation, but also data on private infrastructure investment. The new series include the following infrastructure categories: transport (railroads, roads, urban transport, waterways and ports), communications (telegraph and telephone networks), power distribution (gas and electricity), hydraulic works (dams and irrigation canals) and urban and suburban infrastructure, and their estimation is based on a full range of both public and private sources: government records (for roads, ports or public hydraulic works), private companies' accounts (for railroads, tramways or the telephone system) or, in other cases (such as energy distribution or the telegraph system), physical indicators of the evolution of the infrastructure stock (coming from public statistics or technical and historical literature) which have been valued on the basis of private firms' accounting information or engineering cost reports. The complete sources and infrastructure data set may be seen in Herranz-Loncán (2005b).

Table 1 reports the distribution of infrastructure investment among different categories and its importance within Spanish GDP before 1935; the complete series is depicted in Figure 1 below. The most prominent feature in the evolution of Spanish infrastructure is indeed the abnormally high investment rate of the years 1855-1866, which corresponded to the earliest and most intense Spanish railroad mania, and to a substantial simultaneous increase in state investment in the road network, ports and the telegraph system. The investment mania ended in 1866 with a deep crisis and infrastructure construction only resumed in the mid-1870s, at a much lower rate than before.

Table 1

Spanish infrastructure investment rate and composition, 1845-1935 (%)

	Infr. inv./ GDP	Railroads	Urban transport	Roads	Ports	Telecom.	Energy distrib.	Hydr. Works	Total
1845/55	1.19[a]	43.71	0.00	40.42	3.51	0.16	0.57	11.63	100
1856/65	2.80	74.92	0.00	17.23	4.00	0.52	0.20	3.14	100
1866/75	0.78	54.72	0.00	32.73	9.11	0.27	1.10	2.07	100
1876/85	1.08	65.39	0.33	28.05	2.00	0.49	1.81	1.93	100
1886/95	1.13	63.08	0.98	21.45	7.82	1.48	2.33	2.85	100
1896/1905	0.93	44.49	7.27	21.09	15.26	0.54	5.86	5.49	100
1906/15	1.00	31.67	3.73	21.46	16.90	2.12	14.45	9.66	100
1916/25	1.34	21.05	11.70	18.54	7.17	3.52	29.64	8.38	100
1926/35	1.96	15.88	4.56	30.92	8.74	9.53	18.38	12.00	100
1845/1895	*1.42*[a]	*64.67*	*0.15*	*25.76*	*4.20*	*0.67*	*1.06*	*3.50*	*100*
1895/1935	*1.30*	*28.57*	*5.90*	*24.05*	*10.50*	*5.09*	*16.85*	*9.02*	*100*
1845/1935	**1.37**[a]	**39.77**	**4.10**	**24.65**	**8.54**	**3.71**	**11.92**	**7.31**	**100**

Source: Herranz-Loncán (2005b), and GDP from Prados de la Escosura (2003).

Note: (a) Period starts in 1850.

Several periods may be distinguished in the evolution of Spanish infrastructure investment from 1875 onwards. Between this year and 1895 the main feature of infrastructure capital formation was the absolute prominence of the railroads, which absorbed nearly two thirds of the resources invested. During the same period, the road network accounted for 24 per cent of the total resources and the shares of other types of infrastructure remained very small. As a result, by 1895 a railroad network of 12,291 km. had been established that, although not very dense in comparative terms, serviced the whole territory of the country.[1] After that year, railroad capital formation stagnated due to the virtual completion of the main network, and a process of diversification of infrastructure investment started. The reduction in the importance of railroads firstly benefited ports and urban and suburban transport and, later on, irrigation infrastructure, the telephone system and, especially, electricity distribution. Meanwhile, the road network kept a constant share within total infrastructure investment. The diversification of infrastructure investment reached its zenith during the last investment cycle of the

[1] By 1900, the density of the Spanish railroad network was 26 km of line/km^2 of surface, much lower than the French (81) or the Italian one (55); Herranz-Loncán (2002), p. 167.

period under study, i.e. under Primo de Rivera's Dictatorship and the Second Republic (1923-1936). During those years, the government devoted increasing resources to roads, ports and hydraulic works, whereas private investment flourished in the electricity sector, urban transport and the telephone system. The coincidence of state activism with the dynamism of private investment resulted in the highest levels of infrastructure capital formation of the whole period.

In sum, during the late nineteenth and early twentieth centuries a complex infrastructure stock was built in Spain that, despite its limitations, might be expected to have provoked substantial reductions in transaction costs in the economy, and to have opened up prospects for the industrialization of the country. The main component of the new Spanish infrastructure was indeed the railroad system, but its construction was accompanied by an increase in the stock of many other assets. In the next section the new dataset is used to analyze the extent to which the economy responded to that continuous improvement in the availability of infrastructure.

3. Econometric model and results

To approach the growth impact of infrastructure investment, I use a standard production function with one aggregate output (*y*) and three inputs: infrastructure capital (*g*), machinery and equipment capital (*k*) and labor (*n*). All series are taken in logarithms:[2]

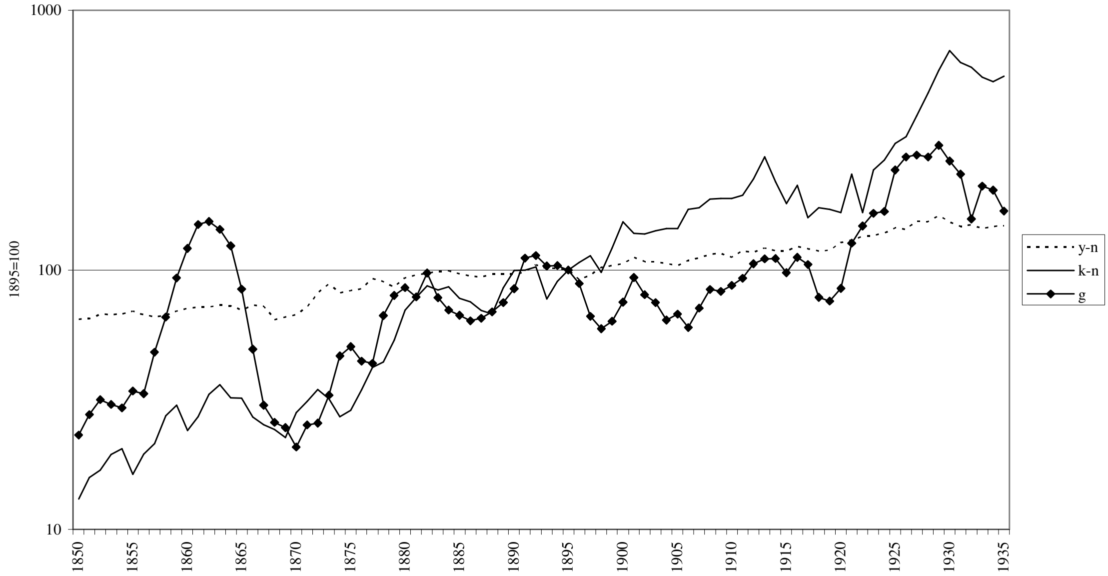
$$y - n = \alpha + \beta_1 (k - n) + \beta_2 \cdot g \qquad (1)$$

This section reports the results of the estimation of model (1) for the Spanish economy during the period 1850-1935. Annual data on GDP, labor, and machinery and

[2] Model (1) assumes constant returns to scale between labor and machinery and equipment capital but increasing returns to scale across the three inputs. An alternative specification might be: $y - n = \alpha + \beta_1 (k-n) + \beta_2 (g-n)$, i.e. assuming constant returns to scale across the three inputs. The estimation results of this alternative model are very similar to those of model (1), and available from the author upon request.

equipment capital come from the recent estimates by Prados de la Escosura (2003), and infrastructure capital has been taken from Herranz-Loncán (2005b); all these series are expressed in real terms. As far as the capital variables are concerned, investment data have been preferred to stock figures. Although capital is usually included in stock terms in the standard production function framework, the use of capital stock variables in a VAR analysis is troublesome, since they are usually integrated of second order, whereas production is highly unlikely to be so (Haldrup, 1998; Otto and Voss, 1996). Therefore, as in other similar analyses (Sturm *et al.*, 1999; Pereira and Andraz, 2005), investment figures have been preferred here, in order to keep the homogeneity among the time-series properties of the data. This choice may involve a loss of information on the longest term relationships between the variables, because using investment instead of stock variables is equivalent to consider only the influence of the pace of growth of capital on output, independently of the stock level. Therefore, the presence of DRS or IRS in the relationship under study may be missing in the analysis. However, on the other hand side, the use of investment variables in growth analyses has been given support from different perspectives by Scott (1993) and Levine and Renelt (1992). In addition, if reverse causation from output to investment is present, the investment decision-making process is better captured by the investment variables than by the stock series. Figure 1 plots the variables of model (1) in order to provide a visual sense of their joint evolution.

Fig 1. Variables of the Model



Sources: Prados de la Escosura (2003) and Herranz-Loncán (2005b).

As a lead-up to the estimation outcomes, Table 2 displays the results of the Granger-causality test for each pair of variables of the model. Although this test does not indicate causality itself, but just precedence or information content, it provides a preliminary approach to the potential relationships among the variables. According to the table, GDP and machinery investment per worker are both helpful in the prediction of all other variables. By contrast, infrastructure investment does not help to predict either output or machinery investment. Thus, the simple evidence coming from the Granger-causality analysis does not support the idea that infrastructure had a positive impact on Spanish economic growth during the country's industrialization.

Table 2

Granger-Causality Tests (2 lags)

H_0	F- stat.
k-n does not Granger-cause y-n	3.15*
y-n does not Granger-cause k-n	4.62*
g does not Granger-cause y-n	1.43
y-n does not Granger-cause g	5.03**
g does not Granger-cause k-n	1.52
k-n does not Granger-cause g	4.49*

* Rejection of the null hypothesis at the 5 percent level.

** Rejection of the null hypothesis at the 10 percent level.

Before estimating the model with non-stationary time series in levels, I test if all the variables are integrated of order one and cointegrated. I have applied in all cases the standard Augmented Dickey-Fuller and Phillips-Perron tests, since the lack of structural breaks in the series does not make the application of alternative test specifications necessary.[3] The test results are shown in Table 3, and they indicate that the hypothesis of the presence of a unit root cannot be rejected in any case.

Table 3

Unit root tests (1850-1935)

Variable	ADF t-stat.	PP t-stat.
y - n	-3.39	-3.39
k - n	-3.09	-3.23
g	-3.33	-2.30

H_0: Presence of a unit root.

[3] All the series have been applied the Vogelsang test, which is aimed at contrasting the existence of one-time breaks in linear trending data in the presence of serial correlation, regardless of whether a unit root is present or not; see Vogelsang (1997). The hypothesis of no structural break has not been rejected for any of the variables.

The model has been subjected to the Engle-Granger and Johansen tests for the presence of cointegration among the variables. The specification of the latter (lag length and deterministic components) has been selected through the application of multivariate generalizations of the Akaike and Schwartz information criteria and the use of the Pantula principle; the optimum system contains two lags and a constant. The outcomes of both tests, which are shown in Table 4, indicate that the existence of a single cointegration relationship cannot be rejected. This allows interpreting the relationship among the variables as structural. Table 5 shows the Engle-Granger estimates of the cointegration relationship.

Table 4

A) Johansen cointegration test (trace).

H_0: No. of cointegration relationships	
None	30.76[a]
At most 1	12.47
At most 2	0.06

B) Engle-Granger cointegration test

H_0: No cointegration among the variables	
Test stat.	4.04[b]

[a] Rejection of the null hypothesis at the 5 per cent level

[b] Rejection of the null hypothesis at the 1 per cent level.

Table 5

Cointegration Equation (VEC model).

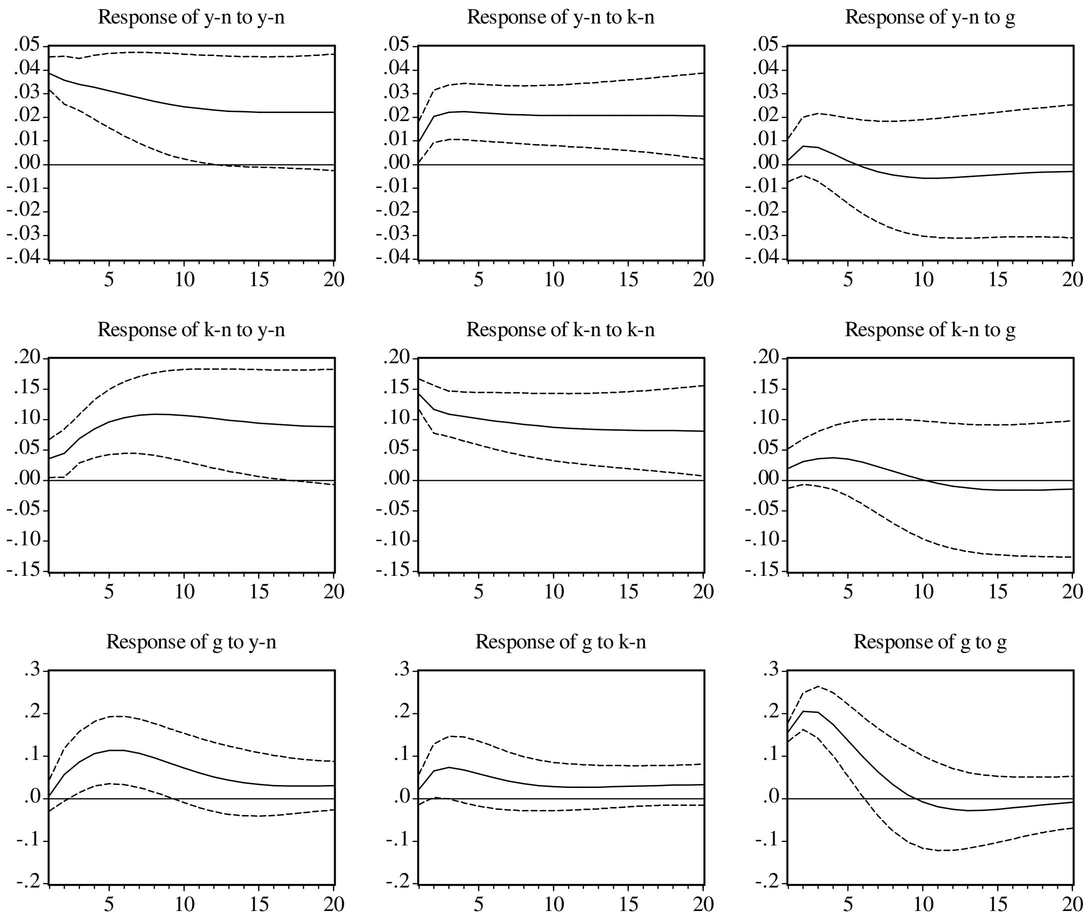
Left-hand variable: *y-n*

k - n	0.240 (0.010)
g	0.008 (0.016)
Constant	-3.856 (0.178)

Note: standard errors in brackets.

The coefficients in Table 5 have the expected sign, showing a positive relationship between the capital variables and productivity. However, the coefficient of infrastructure investment is surprisingly low. If the estimated coefficients were interpreted as elasticities, figures in the table would indicate that, during the period under analysis, a 1 per cent increase in machinery investment per capita resulted in the long term in a 0.24 per cent increase in productivity, but the effect of a 1 per cent increase in infrastructure investment per capita was negligible. These coefficients, however, cannot be interpreted directly as elasticities of output to investment, due to the possibility of reverse causation. In other words, the cointegration relationship may arise, at least in part, because the investment variables were responding to output fluctuations. Actually, this hypothesis has already been suggested by the outcomes of the Granger-causality test, and is confirmed by the results of the impulse-response analysis of the system, which are shown in Figure 2. The impulse-response graphs capture the gradual reaction of each variable to shocks coming from the others when all relationships in the system are considered. Impulse-response estimates have been obtained through the use of Pesaran and Shin (1998) generalized approach, which has the advantage of being invariant to the ordering of the variables. The significance of the effects has been evaluated through the observation of Montecarlo calibrated standard errors, which are also reported in the graphs.[4]

Fig. 2. Impulse-response analysis of the system



The results of the income-response analysis confirm the main intuitions provided by the Granger-causality test. The evolution of GDP per worker exerted a clear influence on both investment variables during the period under analysis. Shocks to productivity had a positive short to medium-term impact on infrastructure construction, and a long-term positive impact on machinery and equipment investment. In turn, as might be expected, shocks to machinery and equipment investment had a long-term

[4] Figure 3 corresponds to an unrestricted VAR system, which does not impose the long-term restrictions associated with the cointegration relationship, but allows them to be satisfied asymptotically.

positive impact on productivity, being machinery investment, therefore, a crucial source of economic growth during the period. By contrast, neither productivity nor machinery investment seem to have responded to shocks to infrastructure investment. In other words, the impulse-response analysis would suggest that the growth impact of Spanish infrastructure investment was negligible during the period under analysis. This result strongly contrasts, for instance, with those obtained for the Netherlands between 1853 and 1913 by Groote *et al.* (1999), who found infrastructure to have a clearly significant positive impact on GDP.

A step further in the explanation of this surprising result may be achieved through the disaggregation of infrastructure investment into two different categories: large transport and communication networks (railroads, roads, ports, the telephone and the telegraph systems) and assets with a local or regional scope (urban transport, power distribution and water infrastructure). There are two reasons that justify this distinction. The first is the relative intensity of the state intervention in each of those two infrastructure categories. The second is associated to their specific network characteristics.

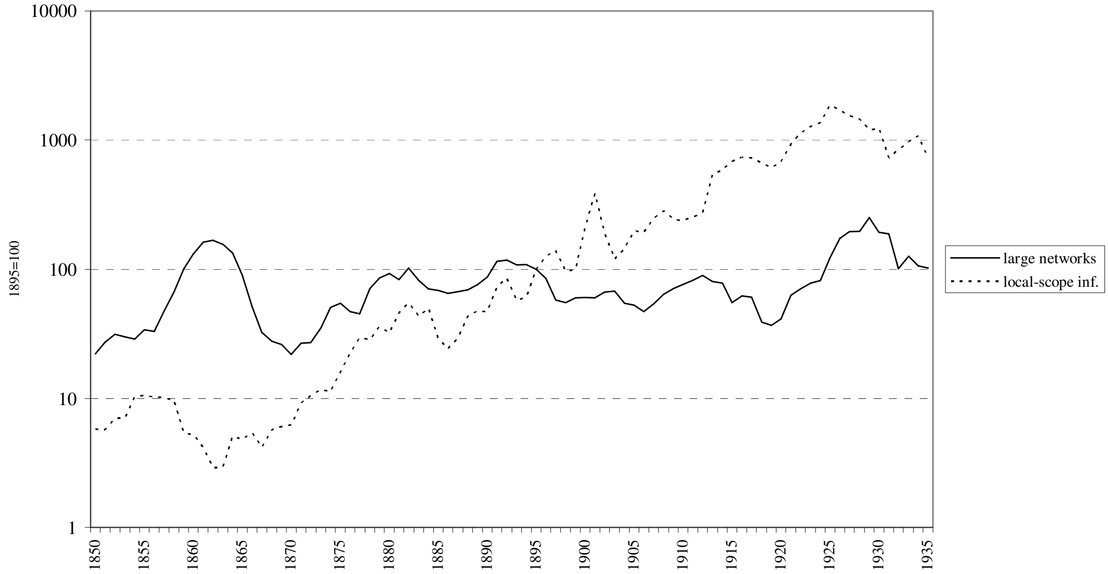
Regarding the first reason, Millward (2004) has recently stressed the differences among late nineteenth century European states' policies in each one of those infrastructure categories before 1914. In the case of the local networks of gas, electricity and urban transport, the evolution of investment was hardly affected by state intervention, and where public (municipal) ownership of those networks developed, it was not aimed at expanding infrastructure but at increasing public revenues. In contrast, in the case of large transport and communication networks, European governments tried to encourage investment in several ways: by guaranteeing returns to capital, by providing subsidies to construction and operation costs, or directly through state ownership. According to Millward, the reasons for governments' attitude towards those nation-wide networks are mainly social and political, such as the potential of the telegraph and the railroads to promote national unification, their capacity to facilitate the dispatch of troops and military supplies, and the governments' interest to control information and the movement of people and goods. In other words, late nineteenth and early twentieth century European governments considered the development of large networks as a means to achieve several social and political objectives, and not merely as an instrument of economic progress.

Research on the allocation effects of investment criteria different from pure efficiency in present economies indicates that the inefficient allocation of public investment may be expected to have an influence on the growth impact of infrastructure, through a decrease in the returns to the resources invested (e.g. Evans, 1991; De la Fuente *et al.*, 1995; Cadot *et al.*, 1999; Caminal, 2004; Castells and Solé-Ollé, 2005). Therefore, *ceteris paribus*, the impact of infrastructure investment may be expected to be lower in the case of those infrastructure industries (such as late nineteenth century European large networks) in which state intervention and the influence of inefficient allocation criteria was higher.

Network arguments also justify a distinction between local-scope infrastructure and large transport and communication networks. Usually, infrastructure analyses assume the services of public capital to be proportional to the resources invested. However, as Fernald (1999) has pointed out, this approach is inappropriate in the case of spatially interconnected networks, where the marginal productivity of any link depends on the capacity and configuration of the rest. More concretely, once the basic links of a large network are established, the marginal productivity of additional links may gradually decrease. This reasoning is consistent with Fernald's own findings that the massive road-building of the 1950's and 1960's in the US had a high impact on productivity but, by contrast, roads appear to have had a normal (or even zero) return since the 1970's. In my research, network expansion should be expected to have decreasing returns in the case of large nation-wide transport and communication systems, rather than in local-scope infrastructure, which was very often made up of isolated assets or small networks with low internal connectivity.

The series of Spanish investment in local-scope infrastructure and large transport and communication networks are shown in Figure 3. They reflect the process of gradual diversification of infrastructure investment that was described in Section 2. More concretely, after the first railroad mania of 1855-1865, when the basic links of the railroad network were built, investment in nation-wide transport and communication infrastructure tended to stagnate, whereas local-scope infrastructure went on growing at a very fast pace until the late 1920's. This might be considered as an indirect sign of decreasing returns to the expansion of Spanish large transport and communication systems.

Figure 3. Spanish investment in large networks and local-scope infrastructure (1850-1935)



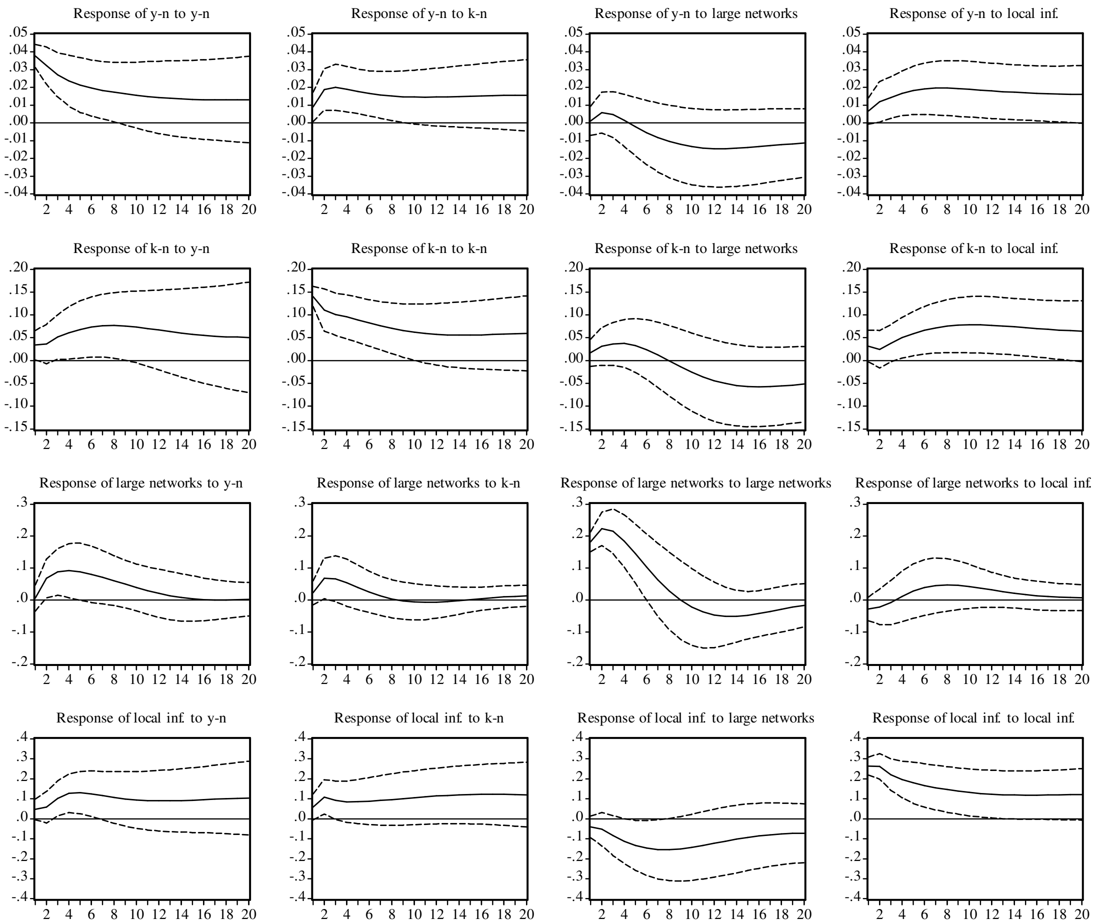
Source : Herranz-Loncán (2005b)

Figure 4 shows the outcomes of the impulse-response analysis of the model when infrastructure is disaggregated into the two categories considered.[5] Most results are consistent with those obtained in the aggregate analysis. Firstly, increases in GDP per worker exerted a positive influence on all kinds of investment. Secondly, machinery and equipment investment had a long-term positive impact on economic growth. Thirdly, as far as the impact of infrastructure investment is concerned, productivity appears to have responded positively to shocks to local scope infrastructure, but not to increases in large transport and communication networks. In addition, according to the graphs, investment in large networks appears to have crowded-out capital formation in local scope infrastructure, i.e. in those assets that had more positive growth effects. In other words, the lack of a significant response of output to shocks in Spanish infrastructure investment, which was found in the aggregate analysis, was actually

[5] For space reasons, the outcomes of the unit-root and Johansen tests are not reported, although they still yield positive results when the infrastructure variable is disaggregated.

driven by investment in large transport and communication networks, both directly and indirectly through its negative effect on local-scope infrastructure growth.

Fig. 4. Impulse-response analysis of the system (two infrastructure categories)



On the basis of these results, the next section addresses two different questions. On the one hand, it analyzes to what extent the two aforementioned features of large networks (i.e. state intervention and decreasing returns to network expansion) were relevant in late nineteenth and early twentieth century Spanish transport and communication systems. And, on the other hand, it explores the extent to which those two factors may explain the lack of response of productivity to increases in infrastructure investment.

4. State intervention and decreasing returns to network expansion in Spanish infrastructure investment

Late nineteenth and early twentieth century Spain is a good example of Millward's (2004) considerations about the different intensity that state intervention had on large transport and communication networks and on local-scope infrastructure. Industries of the second group, such as urban transport and power distribution, largely consisted of small scale undertakings, which stemmed from the initiative of private firms or, in a few cases, from municipal governments with short financial capacity. In those sectors, public intervention to encourage investment was not very important before 1936 (Antolín, 1991 and 1999). The government's role was more relevant in the case of water infrastructure from 1911 onwards, but relatively little was achieved in this field in Spain before 1936 and, as a consequence, most water infrastructure investment had a relatively small scale and a predominantly local or regional scope during the period under analysis (Fernández Clemente, 2000).

By contrast, the government owned most of the road and telegraph networks, and undertook since the mid-nineteenth century an active policy to extend them to the whole country (Herranz-Loncán, 2005b). Along that process, it was constantly criticized for the impact that local lobbies and electoral strategies had on resource allocation (Alzola y Minondo, 1979; García Ortega, 1982; Calvo, 2001). According to the government itself, the influence of non-efficiency objectives and local lobbies implied in some cases the construction of: "two, three and sometimes four roads servicing too abundantly the same public interests, and other going through desert areas, and with such a high cost that it should have been enough to defer its construction in more fertile and populated terrain".[6] At the same time, although the railroads were left in private

[6] R.D. 09/17/1886 (my translation).

hands, the government gave substantial subsidies to their construction in order to encourage their nation-wide expansion, and kept the power to decide over the routes to be built. In particular, the initial 1855 Railroad Act gave preference to the construction of the trunk routes from Madrid to the main ports and frontiers and, later on, the 1870 and 1877 Acts reflected the government's wish to connect all Spanish provinces to the network, and to reduce inequality among provincial railway endowments, according to the so-called "theory of the dispossessed provinces" (Alzola y Minondo, 1979). In sum, in the case of large transport and communication networks, the Spanish government's intervention involved the widespread application of investment criteria different from pure efficiency, such as equity, the administrative and political unification of the country, the influence of lobbies or electoral considerations.

As Millward (2004) illustrates, this situation was not exceptional among the European economies. However, the inefficient allocation of investment might be expected to have had worse effects in Spain than in other countries, due to her low population density. Cost-benefit analysis of road investment indicates that output losses due to the application of non-efficiency investment criteria are higher in countries with large sparsely-populated areas, because the benefit/cost ratio of road projects decreases with population density (Evans, 1991; Glover and Simon, 1975). Spanish population density was one of the lowest in Europe at the time, only higher than in Russia and the Nordic countries,[7] due to both environmental and historical reasons. On the one hand, Spain had one of the highest shares of unproductive terrain in Europe, due to her difficult relief, and the aridity of most Spanish regions was a strict binding constraint for land productivity growth before the twentieth century. On the other hand, the colonization of new lands faced institutional limits in some areas of the country at least

[7] By 1910 the Spanish demographic density was 39.2 inhabitants per square km., i.e. 63 per cent of the Portuguese, 52 per cent of the French and around 30 per cent of the Italian and British equivalent figures.

until the early nineteenth century (Llopis, 2002). In addition, since population was not evenly distributed among the Spanish regions, a large share of the territory was barely deserted. In 1910, the 26 least populated provinces (accounting for 60 per cent of the country's surface), had densities lower than 40 inhabitants per square km., and 14 of them (accounting for 31 per cent of the country's surface) were virtually empty, with less than 25 inhabitants per square km. By contrast, in France, a European medium-density country whose surface was similar to the Spanish one, the *départéments* with less than 40 or 25 inhabitants per square km. only accounted for 10 and 3 per cent of the country's surface, respectively.[8]

Therefore, *ceteris paribus*, a policy addressed to the widespread extension of transport and communication networks would be more costly in Spain than in most European countries, since a high share of investment would be allocated to virtually deserted areas, and would therefore have a rather low benefit/cost ratio. Actually, between 1860 and 1922, 60 per cent of the new road mileage and 52 per cent of the new railroad mileage was constructed in provinces that had less than 40 inhabitants per square km in 1910. In the case of the emptiest areas of the country (with densities lower than 25 inhabitants per square km in 1910), those percentages were 29 and 17, respectively.[9] Out of that investment, a certain share was probably justified from an efficiency point of view, since routes that went across rural areas could be important either as links between two distant urban centers or as ways to export domestic agricultural or mineral products. However, in many cases the economic returns to those undertakings are likely to have been lower than the opportunity cost of the invested

[8] Own calculations from Mitchell (1998).

[9] Own calculation from *Memoria de Obras Públicas* (1860), *Estadística de Obras Públicas* (1922), *Anuario de Ferrocarriles de D. Enrique de la Torre* (1922) and *Censo de Población de España* (1930).

resources, especially if attention is paid to the contemporaries' complaints that many of those routes were the result of electoral strategies or lobbying pressures.

Network arguments may also be helpful to understand the lack of response of productivity to shocks to investment in large transport and communication systems, especially in the case of the railroads. As was outlined in the introduction, the "optimistic" interpretation of the Spanish railroad history has stressed the transport cost-saving effect of the railroads and their impact on market integration. However, the potential impact of each section of the railroad network on the integration of Spanish markets was very different. This may be inferred from the analysis of the gradual changes that the construction of the railroads provoked in the urban market potential of the four largest Spanish cities (Madrid, Barcelona, Valencia and Seville). The market potential of each city is calculated here as:

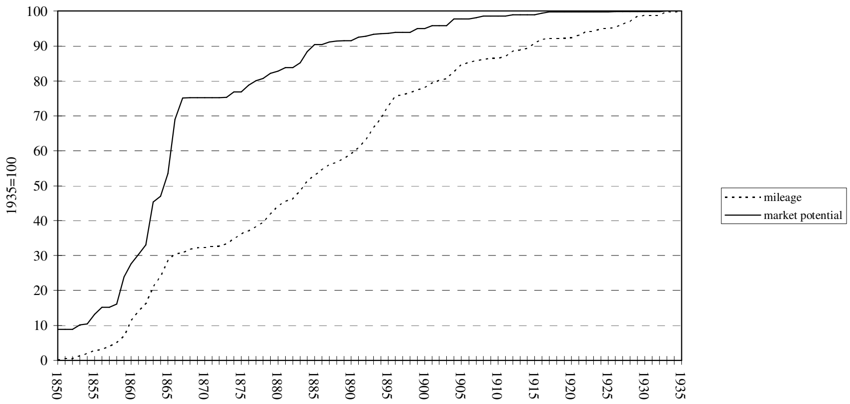
$$MP_i = \sum_{\substack{j=1 \\ j \neq i}}^{n} \frac{pop_j}{d_{ij}} ;$$

where j are the province capital cities and those towns with a population larger than 20,000 during the whole or part of the period 1860-1930, and d_{ij}, is the shortest distance between i and j through the railroad network in each year. Figure 5 shows the evolution of the unweighted average of the urban market potential of the four cities considered, after normalizing it to a level of 100 in 1935. The population data required to estimate that series have been taken from the Spanish censuses,[10] and the distance between each pair of cities has been measured by the author, for each year of the period under study,

[10] In order to make up for the effect of demographic changes, population figures for each town have been set fixed at their 1900 level. Luna Rodrigo (1988) warns that, in some cases, the census data for some municipalities do not correspond to real urban towns but to the administrative aggregation of several small villages. In order to make up for this problem, she excludes from urban population those municipalities that lacked a significant number of high buildings, or which included more than ten population centers, or whose main center was smaller than 5,000 people. This procedure has also been followed here.

through the examination of the effect of the construction of each railroad link on travel routes.

Fig. 5. Spanish railroad mileage and market potential of the main Spanish cities through the railroad network (1850-1935)



Sources: own calculation from information in Cordero and Menéndez (1978), pp. 324-325, Wais (1987) , pp. 255-265 and Luna Rodrigo (1988).

According to the graph,[11] most of the increase in the urban market potential of the main Spanish cities was provided by the links that were constructed before 1866, which constituted the "core" of the network. Those were the lines that connected the main Spanish urban centers among them, and that ran through the wealthiest areas of Spain (such as Catalonia, the Basque Country, Levante or Western Andalusia). Once those basic links had been constructed, there was little margin left for further increases in the market potential of the Spanish cities through the opening of new routes. The railroad lines that were built after 1866 were mostly located in rural and sparsely-populated areas (such as Extremadura, Western Castile or the South-East of Spain) and did not link important urban centers. It is not surprising therefore that they were highly unprofitable and remained underutilized during most of their lives. Actually, they could

[11] The level of the market potential was not the same in the four cities. Differences in the distance to the main urban markets brought the Barcelona and Madrid market potential ca. 20 per cent over and under the average, respectively. On the other hand, the timing of the evolution of the market potential was similar in all cities except Barcelona, where it started growing before, due to the early construction of the first Catalan railroads.

only operate on the basis of a much more intense state intervention than the "core" of the network, with higher subsidies and a much higher leverage ratio (Tedde, 1978; Nadal, 1975). The difference among the two sections of the Spanish railroad network may be observed in Table 6, which reflects the situation of the "core" and the "peripheral" lines at the beginning of the twentieth century, when the railroad system was already fully developed. As may be seen in the table, the density of use of the "peripheral" lines was 53 per cent that of the "core" ones in the case of freight transport, and 42 per cent in the case of passenger traffic. As a consequence, revenues per km. were much lower and financial returns much poorer in the lines that were constructed after 1873. As may be seen in the table, by 1904/1905, when the profitability of the Spanish railroads was close to its historical maximum, financial returns in the "peripheral" lines were only 2.2 per cent of the value of the capital invested, whereas returns to the "core" lines were close to 6 per cent.

Table 6
Density of use and financial returns of Spanish railroads (1904-1905)

	LINES OPEN BEFORE 1873	LINES OPEN AFTER 1873	WHOLE NETWORK
Mileage	7,482	5,672	13,224
Density of passenger traffic (thousand passenger-km per km)	166	89	132
Density of freight traffic (thousand ton-km per km)	247	103	185
Gross revenue per km of line (pesetas)	29,125	13,422	22,313
Net revenue per km of line (pesetas)	15,720	4,667	10,926
Working expenses/Gross Revenue (%)	46	65	51
Net revenue/capital cost (%)	5.63	2.20	4.36

Source: Author's calculations based on data in *Estadística de Obras Públicas* (1904-5).

Note: Figures in the table are not exact, because the source does not distinguish within the different lines of the networks of four companies which were only partially in operation in 1873 (*MZA*, *Andaluces*, *MZOV* and *Asturias, Galicia y León)*. The networks of the first two companies have been included among the lines constructed before 1873, because most of their mileage was already in operation at that date, whereas *MZOV* and *Asturias, Galicia y León* have been included in the other group for the opposite reason.

The Spanish railroads provide therefore a good example of Fernald's consideration that assuming the services of public capital to be proportional to the stock is not an appropriate procedure for the analysis of the growth impact of spatially interconnected networks (Fernald, 1999, p. 624). In Spain, the marginal productivity of railroad investment probably changed dramatically over time, because the construction of the basic railroad links before 1866 would have a much higher impact on economic growth than further additions to the network. To a large extent, this situation may help to explain the outcomes of the estimation of the VAR system. Since the estimation results that have been presented in Section 3 refer to the whole period 1850-1935, the positive growth impact of the links that were built before 1866 is likely to have been made up for in the estimates by the low growth effects and the low benefit/cost ratio of further additions to the network.

5. Conclusions

Using cointegration and VAR techniques, this paper shows that investment in local-scope infrastructure exerted a clearly positive impact on Spanish economic growth between 1850 and 1935. By contrast, returns to investment in large nation-wide networks were not significantly different from zero. The second finding may appear, either as a confirmation of the views of the most pessimistic Spanish railroad historians, or as a surprising result, given the significant transport cost-saving effects of the Spanish railroads and the substantial spatial reorganization of activity that took place in late nineteenth and early twentieth century Spain as a result of market integration. Here I suggest two complementary explanations for the apparent lack of a positive impact of investment in large infrastructure networks on Spanish productivity growth.

Firstly, public intervention was very intense in large transport and communication networks and, as a consequence, non-efficiency criteria were very relevant in the allocation of the resources invested. In that context, output losses due to the application of non-efficiency investment criteria may have been quite high in Spain, due to her low population density. Secondly, returns to new investment may have decreased dramatically over time because, once the basic links of the networks had been built, the opportunities for highly productive investment gradually diminished. Both reasons would have decreased the aggregate impact of investment in large networks to negligible levels, despite the high potential benefits of the construction of the "core" links of those networks. At the same time, as far as different sections of her large infrastructure networks might have had rather different impact, Spain would provide an example of Fernald's (1999) suggestion that the conventional measures of capital and the usual linearity assumptions are not completely appropriate to carry out econometric analyses of the growth impact of this type of networks.

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