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Theofanis Mamuneas[*] and Elena Ketteni

ABSTRACT

The purpose of this paper is to estimate the effect of public infrastructure on the cost structure of European Union (EU) countries and provide an empirical estimate of the rates to return to public infrastructure investment. Using data on transportation, communication, fuels and energy, waste management and water supply expenditures for 27 European countries and for the period 1996 to 2014, we find a significant inducing cost saving from public infrastructure capital stock in all the countries of our analysis. In addition, we calculate the rate of return to public infrastructure and provide evidence of under or over investment of public infrastructure of the EU Member States. The calculated rates of return indicate that all countries benefit from investment in public capital, however the results suggest that Member States, Cyprus for instance, in which the stock of infrastructure is low could benefit more from a well-targeted higher infrastructure investment.

Keywords: infrastructure, translog cost estimation, elasticities, rates of return

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ΠΕΡΙΛΗΨΗ

Σε αυτή τη μελέτη εξετάζουμε την επίδραση του κεφαλαίου για υποδομές στη διάρθρωση του κόστους των χωρών της Ευρωπαϊκής Ένωσης (ΕΕ). Παράλληλα, παρέχεται εμπειρική εκτίμηση των ποσοστών απόδοσης των επενδύσεων για δημόσιες υποδομές. Χρησιμοποιώντας δεδομένα για τις επενδύσεις στις μεταφορές, την επικοινωνία, τα καύσιμα και την ενέργεια, τη διαχείριση αποβλήτων και τις δαπάνες υδροδότησης για 27 ευρωπαϊκές χώρες και για την περίοδο 1996-2014, βρήκαμε μια σημαντική εξοικονόμηση κόστους από το κεφάλαιο δημοσίων υποδομών σε όλες τις χώρες του δείγματος μας. Συγκεκριμένα, τα αποτελέσματα υποδεικνύουν ότι το κεφάλαιο για δημόσιες υποδομές μειώνει το κόστος παραγωγής των χωρών. Επιπλέον, υπολογίζουμε το ποσοστό απόδοσης στις δημόσιες υποδομές και προσκομίζουμε στοιχεία σχετικά με το εάν οι επενδύσεις σε δημόσιες υποδομές στα κράτη μέλη της ΕΕ είναι χαμηλότερες ή ψηλότερες από το επίπεδο που θεωρείται ιδανικό.

Οι υπολογιζόμενοι συντελεστές απόδοσης υποδεικνύουν ότι όλες οι χώρες επωφελούνται από επενδύσεις σε δημόσιο κεφάλαιο, ωστόσο τα αποτελέσματα δείχνουν ότι κάποια κράτη μέλη, όπως για παράδειγμα στη Κύπρο, όπου το απόθεμα κεφαλαίου για υποδομές είναι χαμηλό, θα μπορούσαν να ωφεληθούν περισσότερο από μια καλά στοχοθετημένη υψηλότερη επένδυση σε δημόσιες υποδομές.

1. Introduction

There is considerable empirical evidence that public infrastructure capital contributes positively to lowering costs of production and thus contributes to the growth of output and productivity. Infrastructure refers to technical structures such as roads, bridges, tunnels, water supply, sewers, electrical grids, telecommunications, and so forth, and can be defined as "the physical components of interrelated systems providing commodities and services essential to enable, sustain, or enhance societal living conditions (European Commission, 2014). Public infrastructure is infrastructure that is owned by the public or is for public use.

In a recent report, the European Commission (2014)[1] confirms, for instance, that there is a positive relationship between the growth of transport and electricity infrastructure and economic growth. Policies that promote spending in these areas have a positive impact on growth, provided they do not create excess capacity, as overprovision of infrastructure has been shown to create inefficiencies by diverting resources away from more productive investments. Increased investment in infrastructure can have a positive impact on growth, provided it is well targeted. Evidence suggests that Member States in which the stock of infrastructure is low, or has suffered from underinvestment, could benefit from higher infrastructure investment. The purpose of this paper is to estimate the effect of public infrastructure on the cost structure of European Union (EU) countries and provide an empirical estimate of the rates to return to public infrastructure investment.

To date, there is voluminous literature discussing the effects of different types of infrastructure capital on economic growth and productivity (for a survey see Pereira and Andraz, 2013). Various studies have attempted to clarify the relationship between productivity growth and public infrastructure capital, (using either production or cost functions) and these have found that infrastructure capital contributes to private sector productivity growth. The literature examining the effect of infrastructure capital on output growth and productivity using the production function framework is extensive (for instance see Munnell, 1992; Gramlich, 1994; Nadiri and Mamuneas, 1996; Sturm *et al.*, 1998; Romp and De Haan, 2007; Abdih and Joutz, 2008; Arslanalp et.al, 2010; Albala, Bertrand and Mamatzakis, 2004; Calderon et.al, 2015; Bom and Ligthart, 2014). Production function studies have been conducted at the national level, sectoral level and at different regions or states for many countries. Recent studies that have used the production function analysis at the national level generally find positive and

[1] European Commission, Occasional Papers 203/ December 2014. Infrastructure in the EU: Developments and impact on growth.

significant effects of public infrastructure capital similar to the earlier studies. Production function analysis provides the technological linkage between output, private inputs and public infrastructure but it does not provide a detailed consideration of the effects of public infrastructure on the economic decisions and performance of the firm. Some of the disadvantages of the production function approach can be removed if the optimized behaviour of the firms is taken into account. For these reasons many researchers have used cost or profit functions to investigate the effects of public infrastructure capital.

Most of these studies specify flexible[2] functional forms for the cost or profit functions and are applied to the manufacturing sector in the US or other countries, at the industry, state or regional level. Fewer studies however examine the effect of infrastructure capital on the aggregate private sector of the economy and they find that (for example Lynde 1992; Lynde and Richmond, 1992, 1993a) the publicly financed infrastructure reduces cost and increases the profits of non-financial corporate sector. On the other hand, Mamuneas and Nadiri (2003) find a positive effect of highway capital on the total US while Berndt and Hansson (1991) and Ferrara and Marcellino (2000) estimate a cost function for Sweden (1960-1988) and Italy (1970-1994) respectively and they find that there is evidence of over-investment of public capital stock.

The majority of the above mentioned studies employ a static optimization framework assuming that all factor of production are variable and thus are instantaneously adjusted to their long-run level. There is evidence however that estimating a cost or profit function, assuming that the observed data reflect long-run relationships, might bias the results. Some studies, however, try to avoid this problem by assuming that private capital is a fixed input and instead estimate a variable cost or profit function. These studies find that in all countries public capital has a positive effect on profits and output in all runs (Demetriades and Mamuneas, 2000) or is cost-reducing (Bernstein and Mamuneas, 2007).

In general, the literature points out to positive, significant effects from infrastructure on economic growth and important cost savings. In this paper, we investigate the effect of public infrastructure capital on the cost structure of EU countries. Using data on transportation, communication, fuels and energy, waste management and water supply expenditures for 27 European countries and for the period 1996 to 2014, we find a significant inducing cost saving from public infrastructure capital stock in all the countries of our analysis. In addition, we calculate the rate of return to public infrastructure and provide evidence of under or over

[2] For the definition and properties of flexible functional forms, see Diewert and Wales (1988).

investment of public infrastructure of the EU member States. The next section of our paper presents the methodology and data used in our analysis. In section three the results are reported and the final section concludes.

2. Methodology and Data

In this section we present the methodology and the data used in our analysis. To begin consider the cost function of a country at time t to be given by

$$C = C(w, y, G; t)$$

where w is a vector of the input prices (capital and labor), y is the output and G is the total infrastructure capital stock. It is assumed that the cost function can be approximated by a translog cost function,

$$\begin{aligned}\ln C = a_0 + \sum_k a_k D_k + \sum_i c_i \ln w_i + \frac{1}{2}\sum_i \sum_j c_{ij} \ln w_i \ln w_j + \sum_i c_{iy} \ln w_i \ln y + \frac{1}{2} c_{yy} \ln y^2 \\ + c_y \ln y + c_t t + \frac{1}{2} c_{tt} t^2 + \sum_i c_{it}\, t \ln w_i + c_{yt} t \ln y + c_G \ln G + c_{yG} \ln y \ln G \\ + c_{Gt} t \ln G + \sum_i c_{iG} \ln w_i \ln G \qquad (1)\end{aligned}$$

where C, w, y, t, G and D denote respectively total production cost ($C = \sum_i w_i x_i$), the vector of input prices, output, a time variable representing exogenous technological change, the total infrastructure capital stock and a set of dummy variables capturing country effects. The parameters to be estimated are denoted by the $\alpha's$ and $c's$. The $n \times n$ matrix formed by parameters c_{ij} is symmetric ($c_{ij} = c_{ji}$), and must be negative semi definite so that the function is concave in prices. For a cost function to be well behaved, it must be homogenous of degree one in prices if $\sum_i c_i = 1$, $\sum_i c_{ij} = \sum_j c_{iy} = \sum_i c_{ig} = \sum_i c_{it} = 0$.

Applying Shephard's lemma the following share equations are obtained:

$$s_i = c_i + c_{iy} \ln y + \sum_j c_{ij} \ln w_j + c_{it} t + c_{iG} \ln G \qquad i = K, L \quad (2)$$

Where $s_i = \frac{w_i x_i}{C}$ and the shares are affected by the public capital stock.

The Hessian matrix $\partial^2 C / \partial w^2$ should be negative semi-definite so that the cost function is concave in input prices. Also the cost function should be non-increasing in G and non-decreasing in output and also linear homogeneous in input prices.

For our methodology one needs data for the prices and quantities of both the output and the inputs. We obtained relevant data from several publications of Eurostat and the European Commission. The data cover the period 1996 to 2014. The countries included in our analysis are: Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Spain, France, Italy, Cyprus, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Slovenia, Finland, Sweden, UK and Norway.

The variables used in our analysis are: Gross Domestic Product in current prices and constant 2000 prices, Employees (total and self-employees), Total hours worked (man hours, again for total and for self-employees), investment in current prices and in 2000 prices and Compensation of employees. All prices are expressed in constant Euros of year 2000. The measure is millions of Euros.

For the construction of the output variable, we use the GDP in current prices, along with the GDP in constant prices (considered as the quantity of output). Dividing current with constant prices, the price of output is obtained. For labor, necessary data are the price and quantity of labor. The compensation of employees was used as the value of labor, adjusted to include the self-employees, a procedure followed also by the European Central Bank. Having the value of labor and hours worked (again adjusted to include the self-employees) the price of labor was obtained, which was transformed in order to be expressed in 2000 prices. Combining labor price and labor value one can derive the quantity of labor in 2000 prices. Investments, in current and constant prices, were used in order to construct the capital stock. The perpetual inventory method was followed with a constant depreciation rate of 5%, to get the quantity of capital. For the initial value (initial period $t = 0$) of the quantity of capital we use the initial capital stock obtained from the European Commission data.

Following Christensen, Cummings and Jorgenson (1981) and Jorgenson and Nishimizu (1978) in order to be able to compare countries, we require comparable measures of factor inputs and output. To achieve comparability in measuring output and factor inputs one needs to employ purchasing power parities (PPP) of output, capital and labor for all the countries under consideration. Therefore, all price and quantity data are expressed in constant 2000 Euros and are PPP adjusted.

For our infrastructure variable we obtained total government expenditure data by function provided from Eurostat. We used the expenditures of the following categories: transport, communication, fuels and energy, waste management and water supply, aggregated, which capture some of the major components of public infrastructure. The perpetual inventory method was followed with a constant depreciation rate of 4%, to get the quantity of

infrastructure/ public capital stock. For the initial value (period t=0) we use the expenditure/investment obtained from Eurostat.

The data are pooled and the estimation is carried out using the maximum likelihood estimator. We estimate a system of two equations, the cost function and labor share equation. We assume that the errors attached to the two equations used for estimation are jointly normally distributed with zero expected value and a positive definite symmetric covariance matrix.

The effect of infrastructure capital stock on the cost function, that is the elasticity of cost, is given by:

$$\varepsilon_{CG} = \frac{\partial \ln C}{\partial \ln G} = c_G + c_{yG} \ln y + c_{Gt} t + \sum_i c_{iG} \ln w_i \qquad (3)$$

Using the elasticity, one can obtain the rate of return of public capital:

$$\rho = -\frac{\varepsilon_{CG} \frac{C}{G}}{P_d}, \qquad (4)$$

where $P_d$is the acquisition price of public capital investment.

The public capital stock affects not only the cost structure but also the demand for inputs. The elasticity of the demand for inputs is given by:

$$\varepsilon_{iG} = \varepsilon_{CG} + \left(\frac{1}{s_i}\right) c_{iG} \quad (5)$$

From the cost we can also get the elasticities of scale and also the elasticity of cost with respect to the technological change parameter. As well as the own and cross elasticities of inputs.

3. Estimation Results

The parameter estimates obtained from estimating the Cost function and Labor share equations are reported in Table 1.

Table 1: Estimation Results

Parameter	Estimate	SE	P-value
c_{LL}	0.17503	0.01377	0.00000
c_{Ly}	0.09157	0.00609	0.00000
c_{Lt}	0.00000	0.00003	0.89700
c_L	0.41851	0.01352	0.00000
a_0	0.03231	0.04992	0.51700
c_y	0.98511	0.02539	0.00000
c_{yy}	0.00340	0.00635	0.59200
c_t	0.00023	0.00018	0.19900
c_{tt}	0.00000	0.00000	0.04200
c_{yt}	-0.00003	0.00005	0.61600
c_G	-0.01544	0.01590	0.33100
c_{yG}	-0.00281	0.00292	0.33600
c_{Gt}	-0.00003	0.00004	0.43300
c_{KG}	-0.03994	0.00861	0.00000
c_{LG}	-0.08727	0.00609	0.00000
Equation		SE	R^2
Cost		0.0564	0.9988
Labour share		0.0522	0.5313
Log-likelihood			1005.76

The standard errors of the regressions are quite low indicating a good fit and the parameter associated with infrastructure capital stock are significant. In addition the coefficients of the dummy variables (not reported in Table 1) were jointly significant.

The estimates are consistent with the economic theory, that is the own demand elasticities with respect to both private inputs are negative. The scale effect is close to one, indicating constant returns to scale and the technological effect is cost reducing. The effect of the public capital stock on the cost is negative. This implies that increasing infrastructure capital stock induces cost savings. Finally looking at the effect of infrastructure capital on the demands of capital and labor, there is indication that public capital is a substitute for labor and complement with capital (see Appendix, Table B).

Table 2: Elasticities of public capital stock and Rate of Return, (Average 1996-2014)

	Elasticities	Rate
Belgium	-0.00523	0.02431
Bulgaria	-0.03930	0.16724
Czech Republic	-0.02209	0.09622
Denmark	-0.01463	0.06169
Germany	-0.00218	0.01039
Estonia	-0.03929	0.16650
Ireland	-0.01053	0.04554
Spain	-0.00834	0.03844
France	-0.00691	0.03037
Italy	-0.00230	0.01356
Cyprus	-0.02853	0.11674
Lithuania	-0.03898	0.15910
Luxembourg	-0.03094	0.12219
Hungary	-0.02678	0.11496
Malta	-0.01779	0.06838
Netherlands	-0.00894	0.03755
Austria	-0.01357	0.05572
Poland	-0.02617	0.10650
Portugal	-0.01083	0.04549
Slovenia	-0.02618	0.10503
Finland	-0.02552	0.10070
Sweden	-0.01324	0.05255
United Kingdom	-0.00645	0.02545
Norway	-0.03111	0.12665

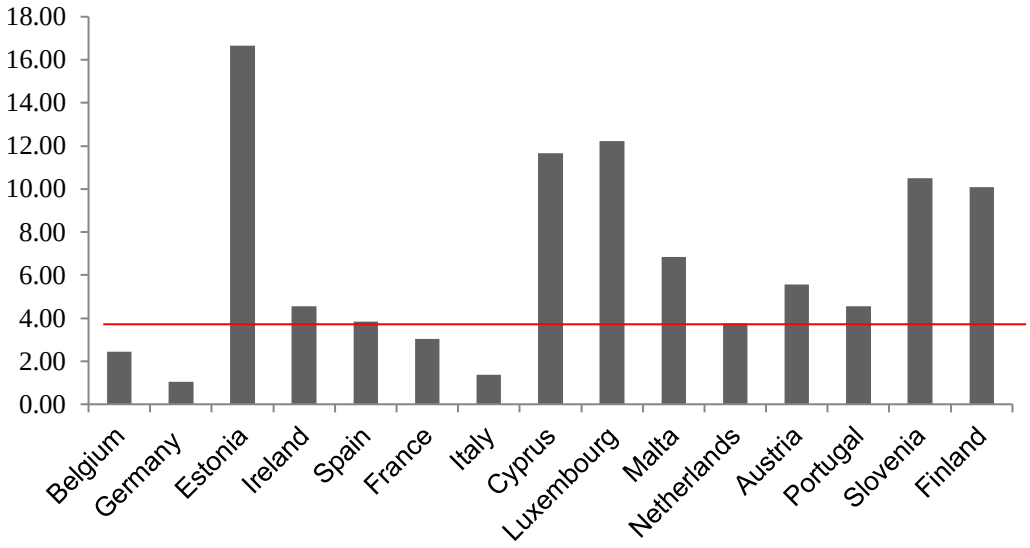
Table 2 presents the elasticities of cost with respect to the infrastructure capital stock per country, as well as the rate of return of public capital. In all countries of our sample the elasticity is negative implying that public infrastructure reduces the costs in a country. Looking at the individual estimates we don't observe much variation between the countries. The average cost elasticities are between -0.039 and -0.0022. Using equation (4) we calculate the rate of return to public capital for each country in our sample. The average rate of return, for the period 1996-2014, is reported in Table 2. The rate of return of public capital is positive for all countries of our sample and it ranges from 1% to 16.7%. We observe that the rate of return does vary, within the countries of our sample. We also observe that the rates have a diminishing effect within time.

While there is not a doubt that increases in infrastructure (transportation, energy, telecommunication) promotes economic growth, however there is a concern that policies that promote spending in these areas might create excess capacity. Overprovision of infrastructure has been shown to create inefficiencies by diverting resources away from more productive

investments (see European Commission 2014). In order to investigate if the infrastructure capital is over or under provided we compare the long-run rate of return to private capital with the rate to public capital estimated in this study. Below we present the average rate of return of the Euro area countries of our sample along with the long-term interest rate (10-year maturity) from the European Central Bank for the euro area.

Figure 1: Rate of return – Euro area 2001-2014

Comparison with long term interest rate (4%)



When the rate of return is higher than the interest rate, this suggests that countries under-invest while a number below the long-term interest rate suggests an over-investment in infrastructure. Clearly there are countries that have an excess capacity of infrastructure for instance Germany and Italy and countries where there is under-investment in infrastructure like Estonia and Cyprus. This suggests that Member States, in which the stock of infrastructure is low, could benefit more from a well-targeted higher infrastructure investment.

4. Conclusion

Provision of public infrastructure is considered by the literature as one of the effective means by which governments can promote economic growth. Government investments, particularly in infrastructure, are considered to have a variety of effects on aggregate output. Firstly, infrastructure can contribute to output directly as a measurable final product. Secondly, as an

intermediate input, it enhances the productivity of all other inputs in producing output indirectly. Thirdly these indirect effects can give rise to externalities, which can cause long-term growth to accelerate.

In this paper we examine the effect of infrastructure capital (that includes transportation, communication, fuel and energy, waste management and water supply) on the cost structure of 27 European economies for the period 1994 to 2014. Our estimation results suggest that public infrastructure induces cost savings and is a substitute for labor and complement with capital. The calculated rates of return indicate that all countries benefit from investment in public capital; however the results suggest that Member States, one such being Cyprus in which the stock of infrastructure is low, could benefit more from a well-targeted higher infrastructure investment.

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APPENDIX

Table A: Descriptive Statistics

	Cost	Cost shares Labor	Quantity of Output	Price of Capital	Price of Labor	Public Stock	Public expenditure* % of GDP
Belgium	296.59	0.65	319.15	0.93	0.91	68.76	3.45
Bulgaria	25.92	0.52	31.29	0.98	0.73	6.07	3.64
Czech Republic	113.51	0.52	128.43	0.92	0.8	39.77	5.26
Denmark	190.18	0.67	210.29	0.96	0.86	28.89	2.12
Germany	2181.67	0.62	2274.33	0.98	0.92	309.38	1.98
Estonia	12.01	0.56	14.09	1.01	0.77	2.39	3.11
Ireland	145.27	0.52	147.49	1.00	0.93	29.21	2.73
Spain	865.17	0.59	918.66	1.01	0.92	180.01	3.01
France	1652.46	0.63	1742.81	1.07	0.94	310.13	2.72
Italy	1336.90	0.55	1431.81	0.96	0.96	305.5	3.06
Cyprus	13.84	0.58	15.4	0.92	0.82	2.37	2.39
Lithuania	23.13	0.51	26.92	0.95	0.76	3.71	2.5
Luxembourg	32.08	0.56	36.8	1.13	0.85	9.48	4.51
Hungary	76.66	0.57	81.17	1.06	0.85	17.92	3.38
Malta	5.03	0.57	5.56	0.86	0.93	1.11	3.06
Netherlands	499.00	0.63	530.3	0.92	0.92	106.91	2.98
Austria	243.62	0.61	261.27	0.94	0.91	55.86	3.28
Poland	267.43	0.51	292.1	0.93	0.81	56.23	3.39
Portugal	140.12	0.63	145.46	0.88	0.94	31.63	2.91
Slovenia	27.94	0.67	29.72	0.97	0.88	5.3	2.79
Finland	149.92	0.62	161.81	1.08	0.87	24.4	2.24
Sweden	294.45	0.63	333.8	0.88	0.9	64.72	3.22
United Kingdom	1644.94	0.66	1686.59	0.97	0.96	293.82	2.46
Norway	255.94	0.53	333.03	0.93	0.77	45.05	2.86

*Public expenditure include expenditures on transport, communication, fuel and energy, waste management and water supply

Table B: Effect of infrastructure on input demands

	Elasticity of Capital	Labor
Belgium	0.1120	-0.1398
Bulgaria	0.0440	-0.2092
Czech Republic	0.0625	-0.1897
Denmark	0.1063	-0.1462
Germany	0.1051	-0.1425
Estonia	0.0521	-0.1960
Ireland	0.0743	-0.1806
Spain	0.0910	-0.1559
France	0.1019	-0.1456
Italy	0.0880	-0.1638
Cyprus	0.0687	-0.1793
Lithuania	0.0426	-0.2124
Luxembourg	0.0601	-0.1871
Hungary	0.0668	-0.1807
Malta	0.0758	-0.1713
Netherlands	0.1000	-0.1485
Austria	0.0889	-0.1582
Poland	0.0555	-0.2007
Portugal	0.0989	-0.1517
Slovenia	0.0975	-0.1574
Finland	0.0819	-0.1658
Sweden	0.0971	-0.1523
United Kingdom	0.1135	-0.1396
Norway	0.0535	-0.1974

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