TOPIC 20
REGIONAL IMPACT
MODELLING

THE LINKAGES BETWEEN TRANSPORTATION INVESTMENTS AND THE REGIONAL DEVELOPMENT: FLAWS IN THE MACRO-ECONOMIC APPROACH

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Abstract

The purpose of this paper is to provide a better understanding of the linkages between the transportation infrastructure investments and the regional industrial development. The underlying hypotheses, the procedures and the findings of the macro-economic approach are examined. After the analysis, it appears that the macro-economic approach is irrelevant and its results lack explanatory and prediction value.

INTRODUCTION

In our era of globalization of the economy, the great nations show the willingness to enhance at home and abroad the competitiveness of their most efficient industries. Two large markets are forming. One is in North America, where the NAFTA (North America Free Trade Agreement) will create a huge market consisting of the United States, Canada, and Mexico. The other one is the European Community.

The enlargement of the market is achieved by homogeneous regulations and taxes, the abolition of tariffs and the decrease in transportation costs. These can make goods produced in one area (a region or a nation) more competitive in another area by reducing their sale costs. The first obvious advantage of the enlargement of the market for each national industry is the *potential* increase in the demand for its production. But not all "national" or "regional" industries are equally prepared to face the enlargement of the market.

In recent years in Europe, studies funded by the European Community or national governments have examined the effects of the large infrastructure links planned or already achieved within the European Community in the context of the opening of the market. These studies showed the emergence of "gaining" regions and "losing" regions according to the now established terminology. However, the methodologies used in these studies are neither clear nor totally explained.

At the same time, each national government intends to prepare its regions to face the opening of the market and to join "gaining" regions. Here two contradictory purposes are encountered. The first is to keep and increase the advantages accumulated by the more developed regions which are more likely to benefit from the opening of the market. The second is to maintain a social equity among the regions and to correct the regional disparities. This concern is very strong in France and shared by the central government and by the local elected officials. The latter generally believe that good public infrastructure will help their regions by attracting new firms or by favouring the existing ones. Their belief is almost an incantation. No clear understanding of the mechanisms that make regions gaining or losing has been yet provided. A better understanding could shed light on the public debate and help to define a public policy.

The transportation infrastructure has a key role in the enlargement of the market, the distribution of goods from the producers to the consumers, the circulation of the flows of inputs between the different producers. Yet it is difficult to measure its contribution to economic growth or development. This paper focuses on the way the transportation infrastructure takes part in the industrial development of the regions. The macro-economic approach is examined as a means to understand the role of the transportation infrastructure in regional development and to provide valid and relevant results.

The macro-economic approach consists of two equivalent sub-approaches: the production function approach and the cost function approach. Both sub-approaches are examined. This analysis leads to the rejection of the theoretical framework of the macro-economic approach. Rejecting this framework, one can allow for increasing returns to scale in the industrial activities. It will be shown how increasing returns to scale permit a better understanding of the industrial development in the regions and the role the transportation infrastructure can play in this development.

THE PRODUCTION FUNCTION APPROACH

In order to assess the contribution of public capital to private output or to private productivity, many studies have used neoclassical production functions where public capital stock is introduced as a factor of production. The other production factors are labor and the stock of private capital. The general relation is the following:

$$Q_{jt} = f(K_{jt}, L_{jt}, G_{jt}) \quad (1)$$

where :

K is the stock of private capital used in the production for a given period of time,

L labor used in the production for the same period of time,

t is the time period, *j* is the unit of observation ie the Region, the State or the Nation considered,

G is the stock of public capital eg transportation infrastructure, water and sewer systems, and sometimes hospitals, schools and other buildings, used in the production during the same period of time. One can separately introduce different types of infrastructure in order to assess their individual contributions. Generally in the studies, *G* is the stock of public capital existing in the geographic area without introducing the degree of utilisation of this capital.

Generally, the studies have chosen a Cobb-Douglas production function which allows perfect substitutability between the factors of production, as follows:

$$Q_{tj} = A_{tj} K_{tj}^{\alpha} L_{tj}^{\beta} G_{tj}^{\gamma} \quad (2)$$

The following log-level form of (2) has been tested:

$$\text{Log}Q_{tj} = \lambda + \alpha \text{Log}K_{tj} + \beta \text{ Log}L_{tj} + \gamma \text{ Log}G_{tj} + \varepsilon_{tj} \quad (3)$$

where ε_{tj} is the error term. α, β and γ are the output elasticities for private capital, labor and public capital respectively (the elasticity is the percentage of increase obtained by one percent increase in the stock of public capital). The correlation between these three factors considered as independent variables and the private output or the private productivity is studied for a given region over several periods, or for different regions over a given period or several periods.

Certain studies have also tested a Translog production function as follows:

$$\begin{aligned}\text{Log}Q_{jt} &= \lambda + a_1 \text{ Log}K_{jt} + a_2 (\text{Log}K_{jt})^2 + a_3 (\text{Log}K_{jt})(\text{Log}L_{jt}) \\ &+ a_4 (\text{Log}K_{jt})(\text{Log}G_{jt}) + b_1 \text{ Log}L_{jt} + b_2 (\text{Log}L_{jt})^2 + b_3 (\text{Log}L_{jt})(\text{Log}G_{jt}) \\ &+ c_1 \text{ Log}G_{jt} + c_2 (\text{Log}G_{jt})^2 + \varepsilon_{jt} \quad (4)\end{aligned}$$

It should be noted that in the Cobb-Douglas function, the output elasticity to public capital is constant and does not depend on the levels of the stock of private capital, the stock of public capital and labor. On the other hand, in the Translog function, the output elasticity to public capital depends on the levels of the stock of private capital, the stock of public capital and labor in the unit of observation as follows:

$$a_4 (\text{Log}K_{jt}) + b_3 (\text{Log}L_{jt}) + c_1 + 2 c_2 \text{ Log}G_{jt} \quad (5)$$

The utilisation of a specific production function implies assumptions which should be examined and compared to the observed phenomena.

The studies carried out under the production function approach differ in the data and the econometric techniques used for estimating the production functions. They also differ in the industries whose output or productivity they consider, and in the level of aggregation of the data: Nations, States, Regions or Metropolitan areas. As a consequence, the obtained results differ.

The first well-known results were obtained by Aschauer in 1989 using time-series data for the United States from 1945 to 1985. He considered an aggregated Cobb-Douglas production function at the level of the United States to link the private output and the stock of non-military public capital (highways, streets, education and hospital buildings, sewer and water facilities, gas electric and transit facilities, and other structures and equipment). He regressed the data using OLS (Ordinary Least Squares Techniques) and imposed the constraint of constant returns to scale (the constraint is $\alpha+\beta+\gamma=1$ ie 1% increase in all the inputs increases the output by 1%). He found a private productivity elasticity with respect to the ratio of public to private capital stocks of 0.39. Given the levels of public capital and private capital, this finding implied that one unit increase of

public capital is more productive than a unit increase in private capital and has a rate of return of about 60%. Using the same series and a Cobb-Douglas production function, Munnell (1990) found a private productivity elasticity to public capital equal to 0.34 (measured by output per hour). Based on these results, the authors argued that public infrastructure capital enhances the productivity of the private sector and that the decline in public investment during the nineteen seventies was a major cause of the slowdown in productivity growth.

Certain criticisms were raised against these findings.

First, the time-series data used had a trend over the period considered. Moreover, it appeared that private output and public capital stock had the same trend. Then, one can demonstrate a linear relationship between them; but this relationship does not mean that there is a causation between the two variables. Instead there is a spurious correlation. The trend of private output and the trend of public capital are due to other factors which have not been identified. Before applying linear regression techniques to such series, they have to be tested for non-stationarity and co-integration, and corrected if necessary. This criticism invalidates both the findings and the method utilized.

A second major criticism is related to the direction of the causation. During the fifties and the sixties, private-sector output grew and so did public capital as a consequence of larger resources. After productivity sagged in the late sixties so did public capital expenditures in the early seventies as a consequence of scarcer resources. The growth of public capital can be seen as a consequence rather than the cause of economic growth.

The use of time-series cross section or panel data can mitigate spurious correlations over time. Several States or regions are observed over a period or several periods of time. Munnell (1990) used series from the 48 contiguous States between 1970 and 1986. She found output elasticities to public capital of 0.15, to private capital of 0.31, and to labor of 0.59. When she split the public capital stock in three categories (highways, water and sewer facilities, and other capital stock) within the same production function, the output elasticities were respectively: to labor 0.55, to private capital 0.31, to highways 0.06, to water and sewer facilities 0.12, and to other capital stock 0.01. Eberts (1988) used data from 38 metropolitan areas between 1958 and 1975 to estimate a Translog production function. The output elasticities obtained were: 0.03 to public capital, 0.39 to private capital, and 0.66 to labor.

The drop in the output elasticities to public capital with the reduction of the level of aggregation of the data (from States to metropolitan areas) is not satisfactorily explained by the existence of spillovers. A spillover implies that the public capital located in a metropolitan area may provide productivity benefits outside this area which are not captured when considering the production of the area. The argument would be that by considering a larger area the spillovers would be taken into account and related to the public capital of the larger area. But this would not necessarily lead to an increase in the output elasticity to public capital. For that, the spillovers should contribute to the production of the complementary area more than the stock of public capital in the production of the original area (maintaining all else constant). When the 48 contiguous States are considered, the productivity benefits due to the spillovers are taken into account but they cannot be attributed to the public capital of the State. With the methods mentioned and used above, these benefits are explained by the residual terms but the residual terms are spatially autocorrelated in multiple directions because of the spillovers. Consequently, the elasticities obtained are biased. Only in the extraordinary case where the spillovers are identical and evenly distributed among the States, these estimated elasticities may not be biased. To solve the problem, the structure of the autocorrelation must be assumed. This implies that the direction and the intensity of the spillovers are known and leads to very complicated econometric techniques.

Furthermore, there is the problem of the heterogeneity of the States or the regions considered. Can one estimate the same elasticities for all the States or all the regions considered? Do regional specificities induce specific stages or ways of development? In other words, is the same increase in public capital likely to produce the same effect anywhere, at any time? In order to take into account regional specificities, further refinements have been introduced into the Cobb-Douglas or Translog production functions described above. The individual specificities (ie regional or States specificities) can be taken into account by means of individual fixed effects or random fixed effects. In the first case, for each Region or State, a constant which depends on the Region is

introduced as an independent variable. As the variable is determined for each Region, the effects are fixed. In the second case, it is assumed that the heterogeneity among the States or the regions can be considered as random. This leads to a heteroskedastic model that can be estimated by GLS (Generalized Least Squares) where the appropriate correction is made. When the regional or State effects are accounted for, the positive and significant output elasticities to public capital tend to disappear.

Holtz-Eakin (1992) using State data from 1969 to 1987, repeated the conventional analysis (ie the OLS specification without State effects) and found a positive substantial output elasticity of public capital stock (0.20). He followed the exercise estimating a production function with State random effects and another one with State fixed effects. In both cases, the best estimate of the output elasticity to public capital is zero.

Llanos (1995) used data from the 21 contiguous Regions of France, from 1984 to 1990 in order to assess the contribution of highway capital to the regional manufacturing output. Using a Cobb-Douglas production function, she tested different models. The model with regional fixed effects appeared to be the most suitable. The output elasticity of highway capital is 0.11. However the regional effects seemed to be greater than the effect of highway capital. Moreover the regional effects can contribute positively or negatively to the manufacturing output according to the Regions.

Indeed, if there are specificities among the States or the regions—it is hard to reject this assumption, at least if it has to be rejected, all the consequences should be examined—the conventional analysis provides wrong estimates and the significance tests are biased. It should be noted that the Translog production function is an attempt, a rigid one perhaps, to model heterogeneity. As shown above (equation 5), for each State the output elasticity to public capital depends on the levels of public capital, private capital and labor existing at a given time in each State. When using a Translog production function estimated among the metropolitan areas, Eberts (1986) found the output elasticity to public capital to be rather small.

The existence of regional or State specificities set the question of the endogenous factors of development. The production function approach is not able to identify nor to take them into account. On the contrary, the three factors (labor, private capital, and public capital) are considered as exogenous in order to apply the regression process to estimate production functions. For example, to estimate a production function, it is implicitly assumed that the formation of public capital is independent of the private output. But it is likely that States or Nations with high level of production have greater resources to spend in public capital. If this is the case, the public capital is no longer an independent variable and the production function cannot be estimated properly. Not to take into account regional specificities implies that the same stocks of labor, private capital, and public capital have the same effect anywhere. Such an assumption does not fit the empirical observation. On the other hand, when taking into account regional specificities, the macro-economic approach does not explain why certain regions are more productive than others. The approach provides no guidance for public policy. Finally, the production function approach relies on strong theoretical hypotheses which were generally neglected in the studies mentioned above. It will be shown later that these theoretical hypotheses do not fit the empirical observations.

THE COST FUNCTION APPROACH

In order to assess the contribution of public capital to private sector productivity the cost function approach has also been explored. In part because of its data requirements, this approach has been less intensively used than the production function one. The goal is to determine a relation between the cost of the output and the prices of the inputs (labor, private capital, and public capital) used in the production. In this relation, public capital is considered as an unpaid factor of production. The necessary data are the market data on prices of private inputs and outputs. In addition to the necessary data to estimate production functions, this approach requires data on wages and on the cost of private capital if it has been physically introduced.

The general relation is the following:

$$C = C\,(Y,P,G,\,t) \tag{6}$$

where Y is the output, C the cost of production of the output, P the vector of prices of the inputs, G the vector of the services provided by public infrastructure and t the level of technology. P and G are exogenous and so are G and t.

To solve the equations, the method uses the optimization behavior of the firms in a perfect market of inputs that can be expressed by the two following hypotheses :

- (H0) The market of inputs is perfect; implying that the prices of inputs are exogenous and common for all the firms.
- (H1) Firms choose the quantities of inputs in order to minimize the cost of production for a given output.

Provided that one chooses "well-behaved" functions to describe the cost function (the functions must have second order derivatives), the marginal benefit due to infrastructure capital is the following:

$$b = (\partial C / \partial G)_{Y,P,T} \tag{7}$$

b will indicate the variation of production cost due to an additional unit of public capital. If b is positive, the increase in public capital leads to an increase in the cost of production. If b is negative, the increase in public capital leads to a reduction in the cost of production. With "well-behaved" cost functions, additional results can be obtained. Let X denote the quantities of private inputs. The elasticity of substitution of inputs to public capital can be obtained by:

$$\forall\,(i,j)\;(\partial X_i / \partial G_j) = (\partial^2 C_i / \partial G_j\,\partial P_i) \tag{8}$$

One can also formally determine if the public capital is undersupplied or oversupplied. That is derived from the comparison between the sum of the marginal benefits of infrastructure capital over all the industries and the economic marginal cost of infrastructure for each type of infrastructure j (ie its opportunity cost). If the sum of the marginal benefits over the industries is superior to the marginal cost of infrastructure, the infrastructure is undersupplied. If the sum of the marginal benefits over the industries is inferior to the marginal cost of infrastructure, the infrastructure is oversupplied. The optimal cost of public capital is obtained when the sum of marginal benefits equals the marginal cost of infrastructure.

The results obtained from the cost function approach differ in the type of infrastructure considered, the level of aggregation of the data (National, State, metropolitan area data, industry data), the industries considered, the assumptions on the behavior of the firms, the cost function used. In most studies, Translog functions have been utilized as well as generalized Leontieff functions. Generally, the increase in public capital is reported to have a cost saving effect on production.

For example, at the aggregated level of the United States, Lynde and Richmond (1992) have estimated a Translog cost function for the non-financial corporate business sector from 1950 to 1989. They assumed a perfect competition between firms and constant returns to scale. They found that public capital diminishes the cost of production, and that labor and public capital are substitutes (with elasticity between -0.45 and -0.49), and private capital and public capital are complements (with elasticity between 0.71 and 0.90).

At the industrial level, Nadiri and Mamuneas estimated a Translog production function for twelve manufacturing industries from 1955 to 1986. They assumed constant returns to scale and introduced a rate of utilisation of public capital. According to industries, the obtained cost elasticity to public capital varies from 0 to -0.21.

The cost function approach offers certain advantages in comparison with the production function approach. The production function approach implies a relation between quantities of inputs and the quantity of output in which the prices of inputs do not enter. The cost function approach is attractive because it addresses the following issues:

- is the public capital undersupplied or over-supplied?
- what is the optimal amount of public infrastructure?
- what are the elasticities of substitution of public capital to private inputs (labor and private capital)?

However, the validity of the above relations and of the results relies on the strong hypotheses (H0) and (H1) and on the assumption that there are constant returns to scale in the industrial production. The adequacy of these assumptions in reality will be subjected to scrutiny in the next section.

THE FLAWS OF THE MACRO-ECONOMIC APPROACH

The macro-economic approach relies on the general competitive equilibrium theory due to the Neo-classical school. This theory consists of a set of basic assumptions which logically establishes the existence of a system of prices satisfying the condition of Pareto optimality. In this framework, the cost function approach and the production function approach are theoretically equivalent. The equivalent set of hypotheses for the production function is the following:

- (H0) As above.
- (H2) The firm maximizes its profit by equalizing the marginal product of inputs and the prices.

The studies using the macro-economic approach have utilized the consequences of these assumptions without examining their relevance nor their ability to explain the facts. Particularly, this optimization behavior makes sense only if the returns to scale are constant in the industrial production.

Indeed, the observations contradict the assumptions of the general competitive equilibrium theory (Kaldor 1967, 1972). In certain industries, there is no perfect competition, there are monopolies or there are regulations to prevent monopolies. During the nineteenth century, the industrial revolution did not develop according to this theoretical construction. The recent mergers in the aeronautic industry for example also contradict the general competitive equilibrium theory.

Yet, the acceptance of increasing returns to scale allows to explain the development of the industrial revolution as well as the contemporary economic events. If there are increasing returns to scale, a general competitive equilibrium is impossible and the firms cannot maximize their profits by equating the marginal costs to the prices. In this case, the macro-economic approach is invalidated and its results cannot provide any understanding of the mechanisms at work.

The role of increasing returns to scale

While the theoretical framework of the macro-economic approach appears to be irrelevant, the acceptance of increasing returns to scale (which are fully recognized in certain manufacturing processes) permits an understanding of the industrial development and sheds light on the role of the transportation investments. The role of transportation investments will be illustrated first, in the case of an enlargement of the market; second, once the enlargement of the market has been achieved, in an existing transportation network.

The case of the enlargement of the market

Consider two geographically defined regions A and B with their industrial organisations. The construction of an infrastructure project linking A and B is considered. What are the effects of this link on the industrial activities of these regions?

The new link permits the enlargement of the market potentially for both the industries located in A and B. The opening of the market is made possible either physically (because a new area becomes accessible) or because of the reduction of transportation costs that may make the goods manufactured in A competitive in B or reciprocally.

The enlargement of the market will benefit the most effective industries, ie those with the lowest average costs of production at the expense of the others. Thus, a growth of activities in certain areas and a reduction in others are to be expected. The global effect will be an increase in productivity in the entire region A+B. The mechanisms through which this result is achieved are set in motion by the existence of increasing returns to scale in manufacturing activities.

The increase in demand due to the expansion of the market allows the industries which are experiencing increasing returns to scale to be even more efficient since the increase in the production leads to a decrease in the production costs. More production is obtained with relatively less inputs and consequently the private productivity increases.

When the enlargement of the market is achieved

Once the industrial reorganisation has been completed, a further increase in public capital is not likely to produce a proportional increase in productivity at the aggregate level. The major effects of the enlargement have already taken place.

New investments may facilitate the circulation of the flows between the complementary industries. They may spur the relocation of some industries to make the system even more efficient. For example, one can observe the deployment of a network of retail sales industries. New investments will be also required for the maintenance of the network of infrastructure and to prevent congestion by organizing for example public transportation. But each of these new investments will have a different rate of retum, whatever the method of evaluation.

The effect of public spending

The public spending injected in a region through transportation investments has a short term effect. This spending is related to the realization of the public investment in the region. It increases the demand by temporarily providing new incomes in the region. By increasing the demand for goods, the public spending amplifies the mechanisms at work as described above, provided that the increase in demand is not import-oriented.

The typology of transportation investments and their effects

It appears that the rates of return of transportation investments are different when the investments serve to enlarge a market and when they occur in an existing network. Transportation investments can be considered according to the mechanisms they serve in developing the economy of one region or between two regions.

1. Investments opening a market

The effects are obtained through the following mechanisms:

- the decrease in the generalized cost of transportation;
- the increase in the demand due to the market enlargement and its consequences on productivity through the increasing retums;
- the specialization made possible by the extension of the market and the further productivity which may result from it through the increasing returns;
- the increase in demand due to the temporary flow of public spending.

2. The investments related to the construction of a new link within an infrastructure network or an increase in capacity of an existing link

- the re-routing of traffic due to the decrease in the generalized cost of transportation;
- a new traffic induced by the decrease in the generalized cost of transportation;

- the increase in the demand for goods due to the flow of public spending;
- the relocation of certain firms.

3. The maintenance investments

The maintenance investments keep the economy of a region efficient. They can be:

- routine maintenance or
- large investments such as in capital projects.

Investments may:

- sustain the level of consumption;
- induce a temporary increase in the demand for goods.

It is clear that the effects of a marginal increase in infrastructure capital on the private output or productivity will be different according to the types of investments. The macro-economic approach cannot distinguish the different types.

On the contrary, for each kind of infrastructure (highways, railways, etc), the approach aggregates all types of investments and provides one value for the elasticity of the total. This elasticity value cannot be used for either explanatory or predictive purposes. The problems set by aggregating different investments invalidate the use of a production function as a purely technological relationship.

It should be noted that to obtain the stock of infrastructure by adding the costs of all the investments is particularly inadequate since the cost of an infrastructure project does not reflect the service provided by the project. This procedure is not valid even in the framework of the macro-economic approach. A solution is to introduce a physical measure of the service provided by the infrastructure (an attempted is made in Llanos (1994) for the highway infrastructure). It should be also noted that using for example a Cobb-Douglas function to estimate the elasticities seems particularly inappropriate. The reason is that a Cobb-Douglas function assumes that the elasticities are constant and that they do not depend on the levels of public capital, labor, and private capital.

CONCLUSION

The purpose of this paper is to examine the validity and the relevance of the macro-economic approach in understanding the linkages between the transportation infrastructure investments and the regional industrial development. Significant flaws have been identified in the approach that cannot be overcome by a refinement in the data nor the econometric techniques. Three main findings are formulated as follows.

1. The rates of returns of transportation investments provided by the macro-economic approach are not valid. It has been shown that the effect of a marginal increase in transportation investment varies according to the type of investment to which it is related (link that opens a market, new link within an infrastructure network, maintenance investments) and to the level of industrial development. As a consequence, one cannot aggregate units of infrastructure or infrastructure projects into a stock and estimate the rate of return of the obtained stock. The macro-economic approach does that and provides one rate of return for the aggregation of all the infrastructure investments performed during a given period. This rate of return has neither explanatory nor predictive value.
2. The underlying assumptions of the macro-economic approach contradict the empirical observations. This is an additional and major reason invalidating the method and consequently the results. It becomes necessary to reject this theoretical framework in order to understand the mechanisms through which the transportation investments can take part in the economic development.

3. The acceptance of increasing returns in the analysis of the firms' behavior permits a better understanding of the regional industrial development and the roles of the transportation investments.

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