Regional Science and Urban Economics 43 (2013) 695–706

Contents lists available at SciVerse ScienceDirect

Regional Science and Urban Economics

journal homepage: www.elsevier.com/locate/regec

# The productivity of transport infrastructure investment: A meta-analysis of empirical evidence ☆

Patricia C. Melo *, Daniel J. Graham, Ruben Brage-Ardao

*Centre for Transport Studies, Department of Civil and Environmental Engineering, Imperial College London, London SW7 2AZ, UK*

ARTICLE INFO

*Article history:*
Received 3 January 2013
Received in revised form 16 April 2013
Accepted 20 May 2013
Available online 25 May 2013

*JEL classification:*
H54
O40
R11
R15

*Keywords:*
Meta-analysis
Transport infrastructure
Economic performance

ABSTRACT

Investments in transport infrastructure have been widely used by decision makers to encourage economic growth, particularly during periods of economic downturn. There has been extensive research on the linkage between transport infrastructure and economic performance since the late 1980s, characterised by widely varying evidence. We conduct a meta-analysis of the empirical evidence on the output elasticity of transport infrastructure, based on a sample of 563 estimates obtained from 33 studies. Previous meta-analyses have focused on total public capital and hence cannot appropriately explain the wide variation in the productivity effect of transport infrastructure nor provide guidance to policymakers on the returns to investment in different types of transport infrastructure. Our results indicate that the existing estimates of the productivity effect of transport infrastructure can vary across main industry groups, tend to be higher for the US economy than for European countries, and are higher for roads compared to other modes of transport. The variation in the estimates of the output elasticity of transport is also explained by differences in the methods and data used in previous studies. Failing to control for unobserved heterogeneity and spurious associations tends to result in higher values, while failing to control for urbanisation and congestion levels leads to omitted variable bias. These findings can be used to inform future research on the choice of model specification and estimation and transport-related policy making.



## 1. Introduction

The study of the effect of transport infrastructure on private output has been the focus of extensive research over the past decades and has produced widely varying results. Transport infrastructure has been hypothesised to impact on the economy by different strands of economics. Classical location theory emphasised the role of transport costs as a determinant of the location of economic activities (Weber, 1928; Moses, 1958; Alonso, 1964). The New Economic Geography (NEG) also emphasises the role of transport costs as a location factor within the context of imperfect competition and different degrees of interregional labour mobility (Fujita et al., 1999; Fujita and Thisse, 2002). The macroeconomic theory of endogenous growth also developed a framework in which public infrastructure (including transport infrastructure) can be defined as a source of economic growth through its contribution to technical change (Aschauer, 1990; Munnell, 1992; Hulten and Schwab, 1991; Garcia-Mila and McGuire, 1992).

Alongside a reduction in transport costs, transport improvements lead to a reduction in firms' input costs and thus increased factor productivity. In addition, lower production and distribution costs induced by transport improvements can also result in scale effects and foster competition levels, which in turn result in higher overall productivity levels due to a natural selection process in favour of more productive firms (Nocke, 2006; Baldwin and Okubo, 2006; Melitz and Ottaviano, 2008). Another important contribution of transport to economic productivity relates to what the literature generally terms as 'transport-induced agglomeration effects'. Agglomeration economies occur when economic agents (firms, workers) benefit from being close to other economic agents. Transport improvements can increase the strength of agglomeration economies to the extent that they increase connectivity within the spatial economy. By changing the way people and firms have access to economic activity, transport affects the realisation of agglomeration externalities and hence the productivity effects derived from it (e.g. Eberts and McMillen, 1999; Graham, 2007).

The hypothesis that investments in transport infrastructure produce strong economic benefits and foster growth has justified government funding for new and improved transport infrastructure. This view is supported by early estimates of the output elasticity of transport, which have been criticised since the late 1990s on the grounds of model misspecification and spurious relationships. The first estimates of the impact of transport investment on the economy



* Corresponding author at: Centre for Transport Studies, Imperial College London, London SW7 2AZ, UK. Tel.: +44 20 7594 5924.
*E-mail address:* patricia.melo@imperial.ac.uk (P.C. Melo).

0166-0462/$ – see front matter © 2013 The Authors. Published by Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.regsciurbeco.2013.05.002

relied heavily on models affected by two main estimation issues in this empirical literature, namely: (i) simultaneity bias, and (ii) omitted variable bias. Simultaneity bias results from reverse causality between economic output and transport investment, while omitted variable bias is a problem of model misspecification which occurs when relevant covariates are not considered in the regression model. Both estimation issues result in inconsistent estimates of the output elasticity of transport.

The realisation that estimates obtained from early studies are plagued by spurious associations between transport and economic output has practical implications for policy making, in particular, the widely invoked political belief that transport investments deliver large economic benefits. In fact, the role of transport investment on the economy is considered so crucial that on the 6th of September 2010, President Barack Obama announced a six year investment plan with an initial $50 billion infrastructure package to invest in roads, railways and airports (BBC News, 2010). Similarly, Chancellor George Osborne has also announced a £30 billion investment programme in infrastructure, including new road and rail schemes, to boost Britain's poor performing economy (BBC News, 2011). Such statements are based on the principle that investment in transport infrastructure and economic performance are positively linked, forming a key justification for the allocation of resources to the transport sector.

The productivity effect of transport investments is also being increasingly considered by decision makers and transport planners in their practice of cost–benefit analysis (CBA). The extension of the scope of conventional transport project CBA to include wider economic impacts helps make the case for investment in transport infrastructure more convincing. Traditional CBA assumes that transport user benefits capture all the benefits of transport investments under perfectly competitive markets. In practice, the presence of market failures (particularly, externalities) legitimates the addition of wider economic impacts from transport projects to CBA (Venables, 2007; Graham, 2007; Graham and Dender, 2011).

In this research we are interested in the effect of transport infrastructure on private output. There are various survey papers (Munnell, 1992; Gramlich, 1994; Rietveld, 1994; Boarnet, 1997; Banister and Berechman, 2000; De La Fuente, 2000, 2010), and some meta-analyses (Button, 1998; Bom and Ligthart, 2008; Bom and Ligthart, 2009), on the productivity of public capital. However, these review papers have focused on the role of total public capital. Public capital is a broad term that includes different types of capital, which are expected to differ in the degree to which they impact on private output. There is general agreement that core infrastructure (of which transport infrastructure represents a large part) is expected to have a stronger impact than other components of public capital such as hospital buildings, education buildings, and other public buildings (Boarnet, 1997; Bom and Ligthart, 2009).

By conducting a meta-analysis of existing empirical evidence on the output elasticity of transport infrastructure we hope to inform policy making on the expected productivity returns to investment in different types of transport infrastructure (rail, roads, airport, etc.), industry sectors (manufacturing, services, etc.), and over time (i.e. short-run versus medium- and long-run effects). Such detailed information about the productivity of transport infrastructure cannot be obtained from existing meta-analyses of total public capital. Moreover, the wide variation in the existing estimates of the output elasticity of transport infrastructure also provides a justification for carrying a transport-specific meta-analysis of the empirical literature.

There are a number of very useful surveys on the economic effect of transport infrastructure (Gillen, 1996; Boarnet, 1997; Jiang, 2001). However, these surveys have relied upon traditional literature review techniques. To the best of our knowledge, this is the first meta-analysis of the empirical evidence on the effect of transport infrastructure on economic output. The two main objectives of this meta-analysis are to identify the factors explaining the wide range of results found in the empirical literature and provide guidance to policy makers on the expected returns to investment in transport infrastructure.

The data used in the meta-analysis include studies that use a production function framework to estimate output elasticities of transport. The sample consists of 563 elasticity estimates obtained from 33 studies. Besides summarising the estimates, we estimate meta-regressions to test for the impact of different study characteristics as sources of variation on existing empirical results. The hypothesised sources of variation relate to the following study features: (1) econometric estimator, (2) model misspecification, (3) data aggregation, (4) measurement of transport, (5) transport mode, (6) country and time period, (7) industrial sector, and (8) time frame of the elasticity estimate.

The results obtained from our meta-analysis suggest that the criticisms made to estimates of the productivity of public capital can be extended to transport infrastructure. Estimates obtained from studies using estimators that cannot correct for omitted variable bias and unobserved heterogeneity have tended to produce upward biased estimates of the output elasticity of transport. As for the importance of correcting for reverse causality between transport and economic output, the results suggest that instrumental variable techniques tend to be associated with higher elasticity estimates. Model misspecification also affects the results. In particular, we find that studies which do not account for the urbanisation levels and spatial spillover effects tend to also produce upward biased elasticity estimates.

Our findings also indicate that there are some noticeable differences in the magnitude of the output elasticity of transport across economic sectors and transport modes, and that monetary measures of transport, as opposed to physical measures, tend to produce lower elasticity values. In addition, we find that the estimates of the output elasticity of transport tend to be larger for the US than for European countries, which is reasonable given that the US economy is generally more dependent on road transport than that of Europe, and that road transport studies represent a large part of the meta-sample. Finally, the meta-regressions confirm the intuitive result that estimates of the output elasticity of transport are higher in the long-run.

The structure of the paper is as follows. Section 2 describes the main features of the meta-analysis, its advantages and limitations, and the criteria used to select the estimates included in the meta-sample. Section 3 provides a brief overview of the main findings and issues in the empirical literature on the link between transport and economic performance. Based on the literature review, Section 4 describes the study-design factors (meta-regressors) hypothesised to explain the variation underlying the existing empirical evidence. In Section 5 we present and discuss the meta-regression results. We also conduct various publication bias tests in Section 6 to assess whether it has influenced previous findings. Finally, Section 7 summarises the main conclusions.

## 2. Scope of the meta-analysis

Literature reviews describe and summarise a certain field of knowledge as a fundamental step in the creative process of scientific progress. They do not report new results but provide a comprehensive reference of past research to guide future researchers into original research. However, conventional literature reviews can be biased if the criteria followed to include, or ignore, studies in the analysis are not objective. The purpose of a meta-analysis is to identify sources of systematic variation in existing empirical findings through statistical testing of the role of the various study features on the size of the empirical estimates.[1]

[1] Meta-analysis was not introduced into the economic field until the late eighties and early nineties (Stanley and Jarrell, 1989; Jarrell and Stanley, 1990) and was often applied to environmental and non-market asset valuation (Smith and Kaoru, 1990; Walsh et al., 1989; Weitzman and Kruse, 1990). The main idea proposed by Stanley and Jarrell (1989) was to treat literature reviews in the same manner as we investigate any other empirical issue in economics. Since then it has been applied to fields like labour economics, international economics (Rose and Stanley, 2005; De Groot et al., 2005), and urban economics (De Groot et al., 2009; Melo et al., 2009).