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OVERVIEW OF INDICATORS OF COMPETITIVENESS AND REGIONAL GROWTH IN RELATION TO TRANSPORT INFRASTRUCTURE INVESTMENT

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### Change log

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Executive Summary

This document is devoted to describe the main indicators of national and regional competitiveness in the literature. First, we describe some of these indices, describing the methodology used, and their main advantages and disadvantages. Second, we focus on the indicators of national and regional competitiveness in relation to transport infrastructure investment. Finally, we describe the empirical evidence regarding some of the factors that influence competitiveness and economic growth.

Although many indices, models and indicators have been proposed in the literature to measure national and regional competitiveness, there exist two leading indices that measure national competitiveness: The one contained in the IMD’s World Competitiveness Yearbook and the one contained in the World Economic Forum (WEF)’s Global Competitiveness Report. Both studies use composite indicators to integrate large amounts of information into easily understood formats for a general audience. The IMD’s indicator uses approximately 300 criteria to rank 60 countries while the WEF’s indicator uses approximately 170 variables to rank 117 countries. Both indices rely on evidence-based hard data and opinion-based soft data, and in both indicators transport infrastructure investment is considered as an important variable to measure national and regional competitiveness.

The discussion of the role of transport infrastructure in national and regional competitiveness usually concentrates on questions of accessibility. Thus, some accessibility indices have been also analyzed in this document. Following Baradaran and Ramjerdi (2001), we distinguish five major theoretical approaches for measuring accessibility indicators: (1) The travel cost approach; (2) the gravity or opportunities approach; (3) the constraints-based approach; (4) the utility-based surplus approach; and (5) the composite approach.

Finally, in order to analyze the empirical evidence regarding some of the factors that influence national competitiveness and economic growth, we describe some studies that use the meta-analysis. Meta-analysis is a technique to explain the heterogeneity in results found, by relating the results back to characteristics of the data and of the methods chosen.
1. **Introduction**

This document is the third deliverable of the first work package of the I-C-EU project on the Impact of Transport Infrastructure on International Competitiveness of Europe. The I-C-EU project seeks to clarify the relation between transport infrastructure investment and its wider economic impacts, in particular competitiveness and economic growth. The aim of this deliverable is to describe the main indicators of competitiveness and regional growth in the economic literature, focusing on the role that transport infrastructure investment plays in such indicators.

As argued in the first deliverable of the first work package of the I-C-EU project, there is no clear agreement in the literature regarding the definition of competitiveness. Competitiveness can be defined in a narrow sense at the firm level. However, the concept of competitiveness has been extensively used by policy-makers and, thus, a broad definition of competitiveness is needed at the country or regional level. Much effort has been devoted over time to find a proper definition and, thus, there exist a large number of alternative definitions in the literature. Given the complexity to find a proper definition, many indicators, models and indices have been proposed to measure national and regional competitiveness. Section 2 of this document is devoted to describe the main indicators of national and regional competitiveness in the literature. First, we offer a general overview of the different indices used in the literature, describing the methodology used, and their main advantages and disadvantages. Second, we focus on the indicators of national and regional competitiveness in relation to transport infrastructure investment.

Section 3 describes the empirical evidence regarding some of the factors that influence competitiveness and economic growth. Empirical papers in the literature show different results, with estimations that may vary greatly in magnitude. A common tool to verify if such differences are due to differences in the data or due to differences in the methodology, is meta-analysis. We describe some existing meta-analyses that are related to agglomeration and/or public investments. These can thus serve as valuable inputs in cost-benefit analyses.

Finally, section 4 concludes.

2. **Overview of indicators of competitiveness and regional growth**

2.1 **General overview**

Competitiveness has been a central preoccupation of both advanced and developing countries for a long time (Porter, 1990). Thus, many indices, models and indicators have been proposed in the literature to measure national and regional competitiveness. Some authors use a single measure while others use more sophisticated indices. In this section we describe some of the competitiveness indicators that have been proposed in the economic literature throughout the time.

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1 See within the I-C-EU project Smit (2013) for a full description of the different definitions of national and regional competitiveness in the economic literature.
Initially, single measure proxies of competitiveness were used in the literature. Some authors have used the export market share as a measure of international competitiveness (Kirpalani and Baicome, 1987; Lipsey and Kravis 1987). Other authors have used the percentage share of domestic manufacturing in total output. This latter measurement is based on the assumption that in order to be competitive a country’s strength should be based in manufacturing instead of in services (Krugman and Hatsopoulos, 1987). Other authors have focused on measuring the “revealed” comparative advantage of countries (Balassa 1965 and 1977). Fagerberg (1988) suggests that a theory of international competitiveness must establish a link between the growth and balance of payments position of an open economy and factors influencing this process. Moreover, many indicators of technical intensity have been postulated as indicators of competitiveness (Cantwell, 1991; Pavitt, 1984; Patel and Pavitt, 1987). Boltho (1996) considers the real exchange rate as a good measure of short-term competitiveness and the trend in productivity growth as a good measure of long-term competitiveness. However, on a critical survey on different measures of international competitiveness, Buckley et al. (1988) conclude that single measures of competitiveness do not capture all the elements.

Porter (1990) develops the diamond model through studying eight developed countries and two newly industrialized countries. Porter’s diamond model comprises four country specific components (one at each corner of the diamond) and two external variables (see Figure 1). The four country specific components are: (1) factor conditions, (2) demand conditions, (3) related and supporting industries, and (4) firm strategy, structure and rivalry. The two exogenous parameters are: (1) government and (2) chance. This model cleverly integrates the important variables influencing nation’s competitiveness into one model and it has been widely applied in studying the competitiveness of different countries (Bellak and Weiss, 1993; Hodgetts, 1993). However, there is some criticism and ambiguity regarding the signs of relationships and the predictive power of the diamond model (Grant, 1991).

**Figure 1: Determinants of national competitive advantage**

![Determinants of national competitive advantage](image)

*Source: Porter (1990).*

According to Smit (2010), criticism of the ‘diamond theory’ comes from two perspectives: from the management school (Bellak and Weiss, 1993; Cartwright, 1993; Dunning, 1992, 1993; Rugman, 1990, 1991; Rugman and D’Cruz, 1993; Rugman and Verbeke, 1993) and from the
economic school (Boltho, 1996; Davies and Ellis, 2000; Waverman, 1995). On the one hand, the management school suggests that Porter (1990) does not take the attributes of the home country’s largest trading partner into account (Rugman 1990) and fails to incorporate the effects of multinational activities in his model. To solve this problem, Dunning (1992) treats multinational activities as a third exogenous variable which should be added to Porter’s model. However, some authors argue that multinational activities represent much more than just an exogenous variable. Therefore, Porter’s original diamond model has been extended to the generalized double diamond model (Moon et al., 1995) whereby multinational activity is formally incorporated into the model. Moreover, in studying the Austrian economy, Bellak and Weiss (1993) point out that Porter’s framework of analysis on competitiveness has shortcomings for small, open economies. On the other hand, the economic school considers Porter’s analysis unsatisfactory because there is no core theory, it has no ex ante prediction power, and it is a typical partial equilibrium analysis that leads to a misinterpretation of the traditional and new trade theories (Waverman, 1995; Davies and Ellis, 2000; Boltho, 1996).

In addition to Porter’s diamond model, there exist two leading indices that measure national competitiveness: The one contained in the IMD’s World Competitiveness Yearbook and the one contained in the World Economic Forum (WEF)’s Global Competitiveness Report. Both studies use composite indicators to integrate large amounts of information into easily understood formats for a general audience. A composite indicator is formed when individual indicators are compiled into a single index on the basis of an underlying model (Kao et al., 2008).

The national competitiveness indicator prepared by the IMD that appears in the World Competitiveness Yearbook uses approximately 300 criteria to rank around 60 countries. We would like to highlight that the number of criteria differs from year to year and the number of countries being ranked has been increasing over the years. The criteria used by this index (a collection of evidence-based hard data and opinion-based soft data) are grouped into four main factors and 20 sub-factors (See Table 1). The main factors are: (1) economic performance; (2) government efficiency; (3) business efficiency; and (4) infrastructure. National economies are ranked according to their performance against each of these measures. According to Cambridge Econometrics et al. (2004), “although the IMD is comprehensive in the measures explored, the analytical value of the report is limited due to the volume of the measures and the absence of relative weightings for more influential variables coupled with an absence of regression analysis”. However, it is still useful for identifying the recurring factors that are associated with a competitive economy.

The national competitiveness indicator contained in the WEF’s Global Competitiveness Report uses approximately 170 variables to rank around 117 countries. Again, the number of criteria differs from year to year and the number of countries being ranked has been increasing over the years. Similarly to the IMD’s indicator, this index relies on hard data and soft data. The major difference between these two indices is that the WEF places greater reliance on soft data (around two thirds), while for the IMD this is reversed. The variables included in the WEF’s Global Competitiveness Index are grouped into 12 pillars of competitiveness: (1) institutions; (2) infrastructure; (3) macroeconomic environment; (4) health and primary education; (5) higher education and training; (6) goods market efficiency; (7) labor market efficiency; (8) financial market development; (9) technological readiness; (10) market size; (11) business sophistication; and (12) innovation. While the results of the 12 pillars of competitiveness are reported separately, they are not independent, that is, a weakness in one area often has a negative impact in others. The pillars are organized into three subindexes, each critical to a particular stage of development (see Figure 2). The basic requirements subindex groups those pillars most critical for countries in the factor-driven stage (pillar 1 to pillar 4). The efficiency enhancers subindex includes those pillars critical for countries in the
efficiency-driven stage (pillar 5 to pillar 10). Finally, the *innovation and sophistication factors subindex* includes the pillars critical to countries in the innovation-driven stage (pillar 11 and pillar 12).

**Table 1: Factors and sub-factors in the IMD’s World Competitiveness Yearbook indicator**

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<th>Sub-factors</th>
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<tr>
<td>Economic performance</td>
<td>Domestic economy, International Trade, International investment, Employment, Prices</td>
</tr>
<tr>
<td>Government efficiency</td>
<td>Public finance, Fiscal policy, Institutional framework, Business legislation, Societal framework</td>
</tr>
<tr>
<td>Business efficiency</td>
<td>Productivity, Labor market, Finance, Management practices, Attitudes and values</td>
</tr>
<tr>
<td>Infrastructure</td>
<td>Basic infrastructure, Technological infrastructure, Scientific infrastructure, Health and environment, Education</td>
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*Source: IMD’s website: http://www.imd.org/research/publications/wcy/Factors_and_criteria.cfm*

**Figure 2: The WEF’s Global Competitiveness Index framework**

Although the WEF’s and IMD’s indicators are two of the most acceptable indicators of national competitiveness in the economic literature, they are not exempt of criticisms. Thus, Lall (2001) points out that the WEF’s Global Competitiveness Report has deficiencies at several levels. In particular WEF has problems with the model specification, the choice of variables, the identification of causal relations and the use of data. Moreover, many of the deficiencies of the WEF report also appear to be present in the IMD.

Other measures of national competitiveness that can be found in the literature are the UK Government’s Productivity and Competitiveness Indicators or the one contained in the OECD’s New Economic Report (Cambridge Econometrics et al., 2004). On the one hand, the UK Government’s Productivity and Competitiveness Indicators have been chosen on the basis that they have “a strong relationship with competitiveness” and are the “main drivers of productivity”. The report identifies thirty-eight indicators that are grouped under five productivity drivers: investment, innovation, skills, enterprise and competitive markets. On the other hand, the OECD’s New Economic Report focuses on the factors that primarily lead to greater labor productivity and labor utilization, identifying the following factors as having a strong causal relationship with economic competitiveness: (1) ICT usage, (2) innovation and technology diffusion, (3) human capital, (4) entrepreneurship and (5) macro-economic stability.

Regarding the measure of regional competitiveness, Cambridge Econometrics et al. (2004) distinguish between studies that analyze regional competitiveness as a cumulative outcome of factors and studies that focus on a particular driver of competitiveness. The former studies have been applied at the regional level to compare regions with similar structures or natural endowments in order to assess reasons for variation in performance. Regions are usually at differing stages of development and have different socio-economic structures. Therefore, the relative importance of the factors of competitiveness will vary between regions. Some of the factors that have been indentified to affect regional competitiveness are: (1) employment levels and concentration in high-value-added industrial activities, (2) the level of investment by firms in fixed assets and human resources development, (3) the level and nature of education, or (4) the infrastructure endowment.

Regarding the studies that focus on a particular driver of competitiveness, Cambridge Econometrics et al. (2004) selects seven key factors: (1) Clusters, (2) Demography, migration and place, (3) Enterprise milieu and networks, (4) Governance and institutional capacity, (5) Industrial structure, (6) Innovation / Regional Innovation Systems, and (7) Ownership.

In an attempt to unify some key elements on regional competitiveness, Cambridge Econometrics et al. (2004) propose the Regional Competitiveness Hat (see Figure 3). The hat is composed of several layers, namely: (1) regional outcomes: GDP per head; (2) regional outputs: market GVA. Important measures are regional productivity and unit labour costs, but also profits; (3) regional throughputs: the aggregate firm activity in a certain region; (4) determinants of regional competitiveness. The production factors themselves (labour, capital and land) can be found in the first ring. In a second ring, the primary factors of the regional investment climate can be found. The basic categories are infrastructure and accessibility, human resources and the productive environment. These primary factors are influenced by a

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2 The sources that adopt a cumulative approach which are examined by Cambridge Econometrics et al. (2004) are: European Commission- Second Report on Economic and Social Cohesion; Barclays Bank PLC/EDA/RDA- Competing with the World; UK DTI- Regional Competitiveness Indicators; East and West Midlands Benchmark; Joint Venture (Silicon Valley Network)- Silicon Valley Comparative Analysis; ECORDS-NEI- Regional Investment Climate Study.
host of secondary factors, ranging from institutions, internationalisation and technology to demography, quality of place and environment.

**Figure 3: The Regional Competitiveness Hat**

![Regional Competitiveness Hat Diagram](image)

**Source:** Cambridge Econometrics et al. (2004)
2.2 Overview of indicators in relation to transport infrastructure investment

2.2.1 The role of transport infrastructure investment in competitiveness indicators

In general, transport infrastructure investments imply additional transport capacity, increased efficiency and better reliability and service quality. This in turn leads to lower transport costs and time savings. Moreover, better transport infrastructure is the core element for business expansion. Thus, as shown in Figure 4, transport infrastructure investments leads to higher productivity, competitiveness and economic growth (Mačiulis et al., 2009).

![Image of Figure 4: The impact of transport on economic growth]

*Source: Mačiulis et al. (2009).*

In this section we analyze the role of transport infrastructure investment in some of the leading indicators of national and regional competitiveness analyzed in section 2.1. In particular, we analyze the role of transport infrastructure investment in the IMD’s and the WEF’s indicators of national competitiveness. Regarding the regional competitiveness, we analyze the *regional competitiveness hat* in relation to transport infrastructure investment.

As pointed out in section 2.1, the national competitiveness indicator prepared by the IMD that appears in the *World Competitiveness Yearbook* uses approximately 300 criteria. The criteria used to compute the rankings are grouped into 4 main factors, each of them divided into 5 sub-factors. Notice that each sub-factor does not necessarily have the same number of criteria. Thus, each sub-factor, independently of the number of criteria that it contains, has

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3 However, it is worth highlighting that the role of transport costs on total production costs has been historically declining. Moreover, this decline of transportation costs appears to be continuing (see Glaeser and Kohlhase, 2004).

4 This is so as far as the investment project is socially profitable.
the same weight in the overall consolidation of results, that is, 5%. As already mentioned, the main factors used by the IMD’s index are: (1) economic performance; (2) government efficiency; (3) business efficiency; and (4) infrastructure. In turn, the main factor infrastructure is composed by 5 sub-factors: (1) basic infrastructure, (2) technological infrastructure, (3) scientific infrastructure, (4) health and environment and (5) education (See Table 1).

Transport infrastructure investment is measured in the basic infrastructure sub-factor through the following variables: (1) access to commodities: access to commodities is adequately addressed; (2) roads: density of the network, km roads/square km land area; (3) railroads: density of the network, km per square km; (4) air transportation: number of passengers carried by main companies, thousands; (5) quality of air transportation: quality of air transportation encourages business development; (6) distribution infrastructure: the distribution infrastructure of goods and services is generally efficient; (7) water transportation: water transportation- harbours, canals, etc.- meets business requirements; (8) maintenance and development: maintenance and development of infrastructure are adequately planned and financed.

The variables included in the WEF’s Global Competitiveness Index are grouped into 12 pillars of competitiveness which are organized into three subindexes. Unlike the case for the lower levels of aggregation, the weight put on each of the three subindexes (basic requirements, efficiency enhancers, and innovation and sophistication factors) is not fixed. Instead, it depends on each country’s stage of development. For instance, in the case of Burundi—a country in the first stage of development—the score in the basic requirements subindex accounts for 60 percent of its overall score, while it represents just 20 percent of the overall score of Sweden, a country in the third stage of development. The basic requirements subindex contains pillar 1 to pillar 4, with each pillar being weighted 25%. The efficiency enhancers subindex includes pillar 5 to pillar 10 and the weight assigned to each pillar is approximately 17%. Finally, the innovation and sophistication factors subindex includes pillar 11 and pillar 12 and each pillar is weighted 50%. Transport infrastructure investment is contained in pillar 2 and is weighted 50% of the total score that pillar 2 has in the basic requirements subindex. The WEF’s Global Competitiveness Report highlights the importance of transport infrastructure investment stating that:

“Extensive and efficient infrastructure is critical for ensuring the effective functioning of the economy, as it is an important factor in determining the location of economic activity and the kinds of activities or sectors that can develop in a particular instance. Well-developed infrastructure reduces the effect of distance between regions, integrating the national market and connecting it at low cost to markets in other countries and regions. In addition, the quality and extensiveness of infrastructure networks significantly impact economic growth and reduce income inequalities and poverty in a variety of ways. A well-developed transport and communications infrastructure network is a prerequisite for the access of less-developed communities to core economic activities and services. Effective modes of transport—including quality roads, railroads, ports, and air transport—enable entrepreneurs to get their goods and services to market in a secure and timely manner and facilitate the movement of workers to the most suitable jobs.”

In the WEF’s Global Competitiveness Index transport infrastructure is measured through the following variables: quality of overall infrastructure, quality of roads, quality of railroad infrastructure, quality of port infrastructure, quality of air transport infrastructure and available airline seat kilometres.

5 Although congestion might be also a good indicator of insufficient infrastructure, the IMD’s index does not include any measure of congestion.
The regional competitiveness hat proposed by Cambridge Econometrics et al. (2004) is composed of several layers: (1) regional outcomes: GDP per head; (2) regional outputs; (3) regional throughputs and (4) determinants of regional competitiveness. Productivity is generally seen as the most important driver behind GDP per capita and subsequent explanation of differences between regions. To support the various activities within a region, it is important to have an adequate infrastructure capacity. This includes appropriate transport networks (road, rail, sea, and air) and communications capabilities. Measures of congestion (for example, number of cars per km of motorway) could help to indicate where inadequate infrastructure might be holding back development. Thus, in this study the correlation between productivity indicators and infrastructure variables is analyzed, concluding that infrastructure investment is a necessary, but not a sufficient, condition for regional prosperity.

2.2.2 Accessibility and connectivity indices

The discussion of the role of transport infrastructure in national and regional competitiveness usually concentrates on questions of accessibility and connectivity (Docherty et al., 2009; Vickerman, 1989 and 1995). Although precisely quantifying the impact of transport infrastructure investment on national and regional competitiveness is not possible, there is substantial evidence in favour of the assertion that locations with poor transport systems are at a competitive disadvantage when compared with those with high-quality transport infrastructure (Banister and Berechman, 2001). In particular, improved access to input materials and to markets will cause firms in a region, ceteris paribus, to be more productive, more competitive and hence more successful than those in regions with inferior accessibility (Vickerman et al., 1999). Given the importance of the degree of accessibility and connectivity on national and regional competitiveness, in this subsection we will discuss some accessibility and connectivity indicators.

There is no universally acknowledged definition of accessibility. Some authors define accessibility as some measure of spatial separation of human activities, that is, it denotes the ease with which activities may be reached from a given location using a particular transportation system (Morris et al., 1979). Other authors relate the description of accessibility to the state of connectivity. A location is assumed to be accessible if it is connected to other locations via a link to a road or railroad network (see, for example, Bruinsma and Rietveld, 1998) or to an airport or harbour.

Given the difficulty in defining the term accessibility, various indicators with different theoretical backgrounds and complexity have been proposed and implemented in the economic literature. There is no agreement about an accessibility index. Every measure has its advantages and disadvantages and the choice of an accessibility indicator depends upon the objective of the study (Litman, 2012; Scheurer et al., 2007). For example, Geurs and van Wee (2013) describe two different perspectives for accessibility: (1) accessibility seen from the origin, and (2) accessibility seen from the destination.

Baradaran and Ramjerdi (2001), on a review of accessibility indicators, distinguish five major theoretical approaches for measuring accessibility indicators: (1) The travel cost approach; (2)
the gravity or opportunities approach; (3) the constraints-based approach; (4) the utility-based surplus approach; and (5) the composite approach.

The travel-cost approach embodies those accessibility indicators measuring the ease with which any land-use activity can be reached from a location using a particular transportation system (Breheney, 1978; Burns and Golob, 1976; Guy, 1977). The common aspect for this class of accessibility indicators is that the indicator is simply some proxy of the transport cost. The main advantages of this class of indicators are that they are easy to understand and calculate and less demanding on data than other indicators. The main disadvantages are that they neglect variations in the quality of locations and in the value of time among travellers, they are highly sensitive to the choice of the demarcation area (Bruinsma and Rietveld, 1999), and they do not consider the behavioural aspects of travellers (Hensher and Stopher, 1978).

The gravity or opportunities approach includes indicators based on spatial opportunities available to travellers and they are among the first attempts to address the behavioural aspects of travel. This class of accessibility indicators is undoubtedly the most utilized technique among accessibility indicators (Bruinsma and Rietveld, 1998; Brunton and Richardson, 1998; Dalvi and Martin, 1976; Geertman and Ritsema Van Eck, 1995; Kwan, 1998; Levinson, 1998; Linneker and Spence, 1991). The main advantages of this class of indicators are that they are less demanding on input data than other indicators that reflect behavioural aspects, the ease of comprehension and calculations, and the ability to differentiate between locations. Some disadvantages of this class of indicators are their sensitivity to the choice of demarcation area, their deficiency in the treatment of travellers with dispersed preferences, and their ambiguity in what the magnitude of indicators express (dimension problem).

The constraints-based approach addresses some of the limitations of the earlier models by consideration of the temporal dimension of human activities (time constraints) (Hagerstrand, 1970), and the recognition of multipurpose activity behaviour by a space-time prism (Miller, 1999). A frequently adopted indicator within this class is the cumulative opportunity measure or the so-called isochronic indicators that estimate accessibility in terms of opportunities available within predefined limits of travel cost (Breheney, 1978; Dunphy, 1973; Hansen and Schwab, 1987; Sherman et al., 1974).

The utility-based surplus approach is another attempt to include individual behaviour characteristics in accessibility models. Utility-based indicators have their roots in travel demand modelling and the fact that accessibility depends on the group of alternatives being evaluated and the individual traveller for whom accessibility is being measured (Ben-Akiva and Lerman, 1979). The measure of accessibility defined in this way is in monetary units, which enables the comparison of different scenarios. Williams (1977) noted that utility-based accessibility is linked to consumer welfare. McFadden (1975) and Small and Rosen (1981) showed how this measure can be derived in the discrete choice situation for the multi-nomial logit model when income effect is not present. For examples of investigations on utility-based accessibility measures see papers by Niemeier (1997) and Handy and Niemeier (1997). The advantage of this class of indicators is that they are supported by relevant travel behaviour theories. Some disadvantages of this class of indicators are that they demand extensive data on locations and individuals' travel behaviour and choice sets, and that the assumption of non-preservation of an income effect is restrictive. Moreover, they are also difficult to explain to regulators and therefore less used in practice.

The composite approach combines the space-time and the utility-based models into a composite model (Miller, 1998 and 1999). Miller and Wu (1999) develop this approach further to incorporate a departure-based, discrete time network flow model. While this approach
aims at avoiding the problems of the other accessibility measures, its main disadvantage is related to the vast data requirements.

3. Empirical evidence

There is a tremendous amount of literature on regional processes of agglomeration and growth as well as on public investment in general and transport investments in particular. We choose to focus here on a specific strand of literature, which focuses on gathering the results of as many previous studies as possible, in order to make sense of their findings. Sometimes, this leads to a well-explained ‘average result’ – possibly the true number, if one exists – and sometimes it leads to an explanation why different analyses have come to different conclusions. We know that growth, competitiveness and infrastructure contribute to welfare, but the key is how much, and how we arrive at such a number. It is precisely here that meta-analysis can contribute.

3.1 Meta-analyses

One reason why the results of different studies, be they academic or consultancy work, differ so widely is of course that some studies have access to much better data. Another reason is that some studies employ a methodology that is commonly considered more sound. However, even accounting for those, contradictions abound, and we do not know which of these results are actually “true”. Meta-analysis is a technique to explain the heterogeneity in results found, by relating the results back to characteristics of the data and of the methods chosen (Stanley, 2001; Stanley and Jarrell, 1989). In the words of Roberts (2005), meta-analysis “offers a means of objectively explaining why, and quantifying how, estimates differ from a range of empirical studies.”

In order to do so, all available studies on a given research question are gathered and categorized. Their outcomes can be compared to find an “average prediction”, but meta-regression analysis will allow the application of past research to new data – a so-called value transfer (Brander et al., 2012; Rosenberger and Stanley, 2006). We will discuss six such meta-analyses, which all summarize important aspects of the theory of productivity, regional growth, agglomeration, and the role of infrastructure.

3.1.1 Melo et al. (2009)

An important question in urban economics is whether a higher density (of people, firms, production) leads to higher growth. Theory predicts that high densities lead to more frequent interactions of people and thus ideas (Glaeser, 1999); but the power of this relationship is unknown, and it is therefore difficult for policy makers to select the appropriate degree of urbanization to aim for. Infrastructure is an obvious instrument here, since the size of an economically meaningful region is determined by travel time rather than by physical distance, and thus an improvement in infrastructure increases the total amount of people or actors that can be accessed from a centre point (Venables, 2007).

Melo et al. (2009) collect 34 studies that estimate up to 729 unit-free elasticities of output, productivity or wages with respect to population. (Sectoral diversity, which is sometimes also labelled as urbanization, is excluded in this study; see de Groot et al., 2009, below). Each elasticity represents how output, productivity, or wages increases when population is doubled. An elasticity of 0.2 should then be read as an increase of +20%. Figure 5 shows the distribution of the elasticities collected in this meta-analysis, organized by the period that was studied in the respective paper. The authors specifically suggest that in measuring external
benefits, “instead of using the estimates from a single study, those seeking to estimate benefits could use the mean from our 729 estimates.” Already such a ‘vote’ is therefore a valuable contribution to science and policy (Bushman, 1994)

**Figure 5: Elasticity estimates collected in Melo et al. (2009)**

The graph shows that more recent periods have been studied more intensively; most studies find positive results, mainly below 0.2. Melo et al. (2009) then perform a meta-regression. They analyze how the collected elasticities can be traced back to a set of characteristics. The most important of these are listed in **Table 2**, together with the impacts on the elasticities found. Some of these can be interpreted as measurement errors: for example, studies that take differences in human capital into account, found estimated elasticities that are significantly lower – and since we know that human capital differs over space, it should therefore not be ignored in (cost-benefit) analyses. Other variables reflect differences in the real world: the service sector profits more from urbanization than manufacturing; in Sweden, urbanization plays a smaller role than in the US. One aspect that is analyzed is of particular interest to the current study: Melo et al. (2009) registered whether a study used ‘economically meaningful boundaries’, i.e. boundaries that are defined by economic rather than administrative processes. Although they found significant results for this variable in some of their meta-regressions, some of these were positive, and some negative, and the overall result is thus rather inconclusive.

**Table 2: Summary of results from Melo et al. (2009)**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time period analysed</td>
<td>inconclusive</td>
</tr>
<tr>
<td>Countries analysed</td>
<td>France positive, Sweden negative (compared to US)</td>
</tr>
<tr>
<td>Sectors analysed</td>
<td>services positive (compared to whole economy)</td>
</tr>
<tr>
<td>Panel methods used?</td>
<td>negative</td>
</tr>
<tr>
<td>How urbanization was measured</td>
<td>microdata insignificant</td>
</tr>
<tr>
<td>Agglomeration economies included?</td>
<td>when localization is estimated together with urbanization, elasticities are lower</td>
</tr>
<tr>
<td>Controls for human capital?</td>
<td>negative</td>
</tr>
<tr>
<td>Regions analysed</td>
<td>inconclusive</td>
</tr>
<tr>
<td>Elasticity measured: wage, productivity, output</td>
<td>insignificant</td>
</tr>
</tbody>
</table>
3.1.2 Wang, Koopmans and De Groot (unpublished)

In an as yet unpublished study, Wang, Koopmans and De Groot are expanding Melo et al. (2009) (discussed above) by taking infrastructure into account. To this end, they manually collected background data for each of the studies included in the previous analysis, focusing on the density of transport infrastructure in the region that was studied, at the relevant point in time. Results are not available yet, but will indicate to which degree transport infrastructure influences the possibilities for agglomeration economies.

3.1.3 De Groot et al. (2009); Smit (2010)

Where Melo et al. (2009) focused on urbanization only, three different types of sector-related agglomeration were studied by de Groot et al. (2009), following the seminal work of Glaeser et al. (1992). We will discuss an update of that analysis here, as it appeared in Smit (2010) (pp. 33-64). This study includes 73 articles with a grand total of 786 estimates of agglomeration economies; the original study contained just over 300 estimates. Since these estimates could not be meaningfully compared, the authors instead classified them as significantly positive, insignificantly positive, insignificantly negative or significantly negative. Figure 6 gives the vote count from the larger study; for all three agglomeration effects, results are mixed, but more so for specialization effects, where 90 studies found negative and significant results, and 105 positive and significant results. Assuming statistical significance is a meaningful concept (which is not undebated: Ziliak & McCloskey 2008), we see almost equal numbers of diametrically opposing views.

Figure 6: Vote counts from Smit (2010)

Again, these results are regressed upon a set of explanatory variables. The analysis is not based upon elasticities,¹ but the interpretation is still similar: positive coefficients now indicate that the probability of finding positive results increases. We summarize the main results in Table 3, choosing the first analysis from Smit (2010), as this is most comparable to the more easily accessible analysis presented in de Groot et al. (2009).

An important finding is that studies that look at longer periods and/or at data from the USA are more likely to find positive results for competition; studies with North American data are also more likely to find positive results for specialization. We can therefore tentatively conclude that these two processes are stronger in the US than in Europe, and that competition positively influences growth in the long run rather than in the short run. Diversity, on the other hand seems to be stronger in Asia than in Europe; this can be in line with stages of development, where urban environment and high density are important in the earlier stages (Duranton and Puga, 2001), in which many sectors in Asia still find themselves. Again, the

¹ The dependent variable is whether a regression found negative significant, negative insignificant, positive insignificant or positive significant results. This calls for the use of an ordered probit, which hampers interpretation somewhat. More details are given in the appendix of Smit (2010).
controls included matter sometimes, pointing to the possibility of omitted variable bias in some studies; but where these controls don’t matter significantly (as for competition), the flipside is that results apparently are robust to the inclusion or exclusion of these variables.

Table 3: Summary of results from Smit (2010)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Results: specialization</th>
<th>Results: competition</th>
<th>Results: diversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time period analysed (mean year, period)</td>
<td>insignificant</td>
<td>year insignificant, length of period positive</td>
<td>year positive, length of period insignificant</td>
</tr>
<tr>
<td>Countries analysed</td>
<td>USA positive (w.r.t. Europe)</td>
<td>USA positive (w.r.t. Europe)</td>
<td>Asia positive (w.r.t. Europe)</td>
</tr>
<tr>
<td>Sectors analysed</td>
<td>insignificant</td>
<td>insignificant</td>
<td>insignificant</td>
</tr>
<tr>
<td>Panel methods used?</td>
<td>significant</td>
<td>insignificant</td>
<td>positive</td>
</tr>
<tr>
<td>How agglomeration was measured</td>
<td>significant</td>
<td>insignificant</td>
<td>significant</td>
</tr>
<tr>
<td>Population density</td>
<td>insignificant</td>
<td>insignificant</td>
<td>insignificant</td>
</tr>
<tr>
<td>Controls for human capital?</td>
<td>negative</td>
<td>insignificant</td>
<td>positive</td>
</tr>
<tr>
<td>Outcome measured: employment, patents, productivity, output</td>
<td>employment negative</td>
<td>insignificant</td>
<td>insignificant</td>
</tr>
</tbody>
</table>

3.1.4 Nijkamp and Poot (2004)

Button (1998) describes how endogenous growth theory (see within the I-C-EU project Smit, 2013) was linked to infrastructure and public investment in general by the seminal paper of Aschauer (1989), which “led to a major reassessment of the interrelationship between infrastructure investment and economic efficiency”. In a brief overview of studies up to that moment, Button (1998) lists some output elasticities of public capital, where infrastructure is the main expenditure; in an appendix, he also performs a very brief meta-analysis. It is this exact topic that is taken up by Nijkamp and Poot (2004).

Nijkamp and Poot (2004) differentiate between five types of public expenditure: general government consumption, (lower) tax rates, education, defence, and public infrastructure. Of these, education and infrastructure come out as generally positive for long-run growth, but again there is strong heterogeneity in the 93 studies they gathered. Actually, part of those studies consists of qualitative material, and the only way to meaningfully analyse it is by a so-called rough set analysis. Finally, they point at several pitfalls. Most of the studies they found ignored the spatial configuration of processes; parameters seem to change over time; and the endogeneity of government expenditure has not been sufficiently addressed – it surely varies with stages of development, degrees of openness and institutional aspects.

3.1.5 Bom and Ligthart (2012)

Bom and Ligthart (2012) also look at the elasticity of public capital on national and regional output. Their analysis starts from a simple neoclassical growth model, but they also include the effects of neighbouring regions, as well as the other issues brought forward by Nijkamp and Poot (2004). They categorize the different types of investment, reporting different elasticities for each. Effects are stronger in three cases (see Table 4):

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9 Pedro Bom generously made available the most recent version of the paper to us, which is currently under submission, but not available as a working paper. Hence, the figures reported here will differ slightly from those found in earlier versions of their work.
• if expenditure is done by a regional government rather than by national governments;
• if effects are measured in the long run;
• if expenditure is channelled towards “core public capital”, i.e., roads, railways, airports and public utilities.

However, they also note that with 10% depreciation and 4% long-term interest, the threshold for reaching a positive balance of costs and benefits at all would be 0.14, a number that is only reached in long-run core investments.

<table>
<thead>
<tr>
<th>Time period</th>
<th>All public capital</th>
<th>Core public capital</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>regional</td>
<td>national</td>
</tr>
<tr>
<td>Short run</td>
<td>0.086</td>
<td>0.058</td>
</tr>
<tr>
<td>Long run</td>
<td>0.137</td>
<td>0.109</td>
</tr>
</tbody>
</table>

**3.1.6 Celbis et al. (2013)**

A study is underway by Celbis, Nijkamp and Poot (2013) gathering hundreds of analyses of the relationship between infrastructure and trade. Regions with better infrastructure have lower trade costs, just like in Krugman’s NEG model. However, in the real world, infrastructure can be divided in three: what both trade partners have, and what is in between (Limao and Venables, 2001). Estimations for host and target country are estimated with a series of controls for both methodology and regional characteristics. Results are expected later in 2013.

**3.2 Value transfer**

Following up on the predictions we reported for Bom and Ligthart (2012) (see Table 4), we will now perform a short exercise to show how the results from a meta-analysis can be used in practice. Value transfer can be used to shed light on the results from an individual case study, or to give predictions where case studies are not and will not be available. However, it is imprecise, because of measurement errors, problems of generalization and publication bias (Rosenberger and Stanley, 2006). There are many characteristics in every location that will or even can not have been taken aboard in any meta-analysis.

We will use the meta-analyses of Melo et al. (2009), de Groot et al. (2009) and Bom and Ligthart (2012) to test their predictions on the opening of the Danish Great Belt Bridge (in Danish: Storebæltsforbindelsen),10 which connects the islands of Funen and Zealand since 1998. Melo et al. (2009) allows us to predict the impact of urbanisation economies on productivity in Denmark. Similarly, with de Groot et al. (2009), we test whether agglomeration benefits on productivity due to sectoral specialization11 are expected to be positive or negative for the island of Funen, both before and after the addition of the bridge. Since the bridge effectively enlarges the regions on both sides of the Great Belt, we simulate its opening by increasing the population density from the Funen average to the combined average population density of Funen and Zealand, both for 1998. Finally, we use Bom and Ligthart (2012) to predict the elasticity of expenditure on total output growth.

We know from the reviewed meta-analyses that the low degree of urbanisation in Denmark (relative to Western Europe) will go hand in hand with low benefits of agglomeration. An exception is of course the Copenhagen metropolitan area, which spreads over a large part of

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10 Cf. Deliverable 2.1 of the I-C-EU project, “Database of Case Studies and Screening Methodology”.
11 The study also includes competition and diversity as agglomeration effects (following work of Glaeser et al., 1992), but we choose specialization as our example here for purposes of demonstration.
the island of Zealand. The bridge under study connects Funen and thus the Jutland peninsula to Copenhagen. On a national scale, we therefore expect agglomeration effects to increase, as the country effectively becomes smaller. On the other hand, Copenhagen is located on the east side of Zealand, and the travel time to Jutland remains well above two hours by car or train. At such distances, empirical literature rarely finds any agglomeration effect at all, and the effects of distance decay remain strong (Disdier and Head, 2008; Linders, 2005), even as the role of non-spatial proximity increases (Boschma, 2005).

Results for all three examples are illustrated in Table 5. We assume the analysis uses the more advanced econometric methods that are distinguished in the analyses; for mutually exclusive dummies, we only report those that are applicable.

Table 5: Results of value transfer for three meta-analyses

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coeff.</th>
<th>Value</th>
<th>Variable</th>
<th>Coeff.</th>
<th>Value</th>
<th>Variable</th>
<th>Coeff.</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>constant</td>
<td>0.1285</td>
<td>1</td>
<td>productivity</td>
<td>-0.880</td>
<td>1</td>
<td>constant</td>
<td>3.287</td>
<td>1</td>
</tr>
<tr>
<td>D&gt;90</td>
<td>-0.0015</td>
<td>1</td>
<td>services</td>
<td>-0.060</td>
<td>1</td>
<td>Reg-gov</td>
<td>0.029</td>
<td>0</td>
</tr>
<tr>
<td>DSW</td>
<td>-0.1318</td>
<td>1</td>
<td>spec. included</td>
<td>-0.700</td>
<td>1</td>
<td>Core</td>
<td>0.037</td>
<td>1</td>
</tr>
<tr>
<td>DPD</td>
<td>-0.0256</td>
<td>1</td>
<td>comp. included</td>
<td>0.120</td>
<td>1</td>
<td>Spill-agg</td>
<td>-0.019</td>
<td>1</td>
</tr>
<tr>
<td>DHET_CS</td>
<td>-0.0161</td>
<td>1</td>
<td>div. controls</td>
<td>3.650</td>
<td>0</td>
<td>Reg-data</td>
<td>-0.155</td>
<td>1</td>
</tr>
<tr>
<td>DIV</td>
<td>0.0004</td>
<td>1</td>
<td>log pop. dens.</td>
<td>0.004</td>
<td>0.000</td>
<td>Private</td>
<td>-0.019</td>
<td>1</td>
</tr>
<tr>
<td>DHCAP</td>
<td>-0.0635</td>
<td>1</td>
<td>data year</td>
<td>0.920</td>
<td>0.000</td>
<td>Manufact</td>
<td>-0.049</td>
<td>0</td>
</tr>
<tr>
<td>DLP</td>
<td>0.0229</td>
<td>1</td>
<td>length</td>
<td>-0.010</td>
<td>0</td>
<td>CRTS-all</td>
<td>-0.021</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>capital</td>
<td>-1.150</td>
<td>1</td>
<td>Energy-p</td>
<td>-0.124</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>education</td>
<td>2.360</td>
<td>1</td>
<td>Long-run</td>
<td>0.051</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>wages</td>
<td>0.001</td>
<td>1</td>
<td>Spurious-ts</td>
<td>0.156</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>geography</td>
<td>-0.290</td>
<td>1</td>
<td>Spurious-pd</td>
<td>0.045</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>panel</td>
<td>1.760</td>
<td>1</td>
<td>Endog</td>
<td>-0.038</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>pub. year</td>
<td>-0.170</td>
<td>0.000</td>
<td>Sample-med</td>
<td>-0.005</td>
<td>1998</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Date</td>
<td>0.003</td>
<td>2013</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Country</td>
<td>0.000</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>delta-n</td>
<td>1.816</td>
<td>1</td>
</tr>
</tbody>
</table>

12 Sources for the variables and coefficients are as follows:
- for Melo et al. (2009), coefficients come from Table 4 and variable names are explained in that same table.
- for de Groot et al. (2009), coefficients come from Table 14.4; variable names are abbreviated here but are given in the same order.
- for Bom and Ligthart (2012), coefficients come from their Table 3, last column. Variable names are explained in their Table 2.

13 Further assumptions, by paper:
- for Melo et al. (2009), we assume all controls are included. We apply the Sweden dummy in lieu of a Denmark dummy (the reference category here is the US, according to Table 3). We assume total population is studied, not employment, and that our study is based on regionally aggregated data in a panel setting.
- for de Groot et al. (2009), we assume all possible controls are included, and that specialization is not measured as a location quotient. Population densities have been calculated for Funen and Zealand for 1998 based on data from Statistics Denmark.
- for Bom and Ligthart (2012), we choose to assume constant returns to scale on all inputs, and we use fixed effects in a panel setting with a co-integration test, controlling for business cycles with a measure for capacity utilization. The table reported in the paper is based on demeaned variables, but in the table below, the constant has been recalculated to get rid of the centering. In the restricted model, which we follow here, no dummy for Denmark exists, and hence we set the value to zero.
As for urbanization, Melo et al. (2009) leads us to expect negative results here: an increase of population density will lead to a lower productivity. Large contributors to this prediction seem to be the Sweden dummy (see note 3, above) and the DHCAP dummy, which indicates that we controlled for differences in human capital.

For de Groot et al. (2009), interpretation is somewhat more difficult, as the analysis is an ordered probit. Translating the resulting figure to probabilities leads to a prediction of significantly positive results, but only by a slight margin over negative insignificant results in the base situation. Both have a probability of about 31%. However, for the new population density, the probability of measuring significantly positive effects increases to 40%. Figure 7 shows how probabilities change over the different (natural logs of) population density. Vertical lines indicate the lower and higher population density associated with the situation before and after the opening of the bridge.

![Figure 7: Predictions for de Groot et al. (2009)](image)

Note: The legend shows four categories: negative and positive significant at the extremes, negative and positive insignificant in the middle. The typo in the footnote originates with the Stata module aprobpr used.

Finally, Bom and Ligthart (2012) predict a very positive effect of the investment on the Danish economy: an elasticity of 1.5, which suggests an increase in total output that matches the public investment and then adds an extra 50%. This is a high number, and we should take it with a pinch of salt: apart from the date of the analysis and the type of investment, no data specific to the Storebaelt circumstances had to be inserted into the model to render this figure. A deeper analysis of local circumstances will surely be required, and meta-analyses cannot replace cost-benefit analyses.

4. Conclusions

Many indices, models and indicators have been proposed in the literature to measure national and regional competitiveness. However, it has been argued that single measures of competitiveness do not capture all the elements. Instead, composite indicators are proposed. Although there are many indices in the literature, there exist two leading composite indicators that measure national competitiveness: The IMD’s World Competitiveness Yearbook indicator and the WEF’s Global Competitiveness indicator. Both studies consider transport infrastructure investment an important variable when measuring national competitiveness.
The role that transport infrastructure has in national and regional competitiveness is also related to questions of accessibility and connectivity. Thus, some accessibility and connectivity indices have been analyzed.

We have also shown how meta-analyses gather information from a set of studies with varying research subjects and methodologies. Predictions from a meta-analysis will give a rough guess of the effects that are to be expected. Moreover, results from such meta-analyses can in turn be used to make predictions on new situations. These can be of use in practical decision making, for example when actual data is not available for a Cost-Benefit Analysis. Some meta-analyses also allow analysis of different scenarios by adjusting one of the key variables. However, since meta-analyses typically also control for a large set of methodological differences in the studies under review, assumptions on the merits of these methodologies have to be made in order to come to a meaningful result. Moreover, they use preciously few data on local phenomena to reach their result, suggesting a degree of imprecision. Still, in setting acceptable parameters in cost-benefit analyses, meta-analyses are often the most reliable and precise source of information.
References


