The Economic Impact of Infrastructure Investments and Leakages:
A Literature Review

Felix L. Friedt∗ Wesley W. Wilson†
Macalester College University of Oregon

Abstract
This survey is of the growing body of research investigating the economic development effects of transport infrastructure expenditures, and seaport investments in particular. Much of the literature evolved from early studies that examine the effects of general public capital expenditures on macroeconomic productivity and labor markets. Based on this context, we provide a detailed survey of the research investigating the direct and indirect effects of transport infrastructure investments. Our survey suggests that the relevant and more recent literature continues to be characterized by an ongoing debate about the magnitude of the resulting earnings, productivity and employment benefits and that the reported findings with respect to seaport investments are particularly contentious. Highlighting the most recent advances in this field of study, we summarize the various methodologies and empirical results underlying these controversial findings. We identify cross-border investment benefit leakages as a critical determinant and our survey is the first to review the sparse literature on this topic. We succinctly summarize the key insights regarding the international distribution of national transport investment benefits and identify the remaining gaps of knowledge that deserve more attention going forward.

JEL codes: (R4, R12,O18,L9)
Key words: Transport Infrastructure Investment, Seaports, Benefit Leakages

∗Department of Economics, Macalester College, 1600 Grand Avenue, Saint Paul, MN 55105; ffriedt@macalester.edu.
†Wesley W. Wilson, Department of Economics, University of Oregon, Eugene, OR 97403-1285; wwilson@uoregon.edu.
1 Introduction

The tremendous growth of domestic and international trade as well as the increasing movement of people continue to outpace infrastructure investments globally. In the United States, for example, international trade topped $3.5 trillion in 2016 and involved the transportation of over 48 million containers according to the World Bank. In addition, the OECD database reveals that U.S. transport infrastructure investment and maintenance spending reached merely $93 billion during the same year. Despite the investments, infrastructure has still aged, and the growth in trade as well as the associated transport services have put increased pressure on the infrastructure network in the U.S. and other developed countries. Road and seaport congestion, such as the recent backlogs at the ports of Los Angeles and Long Beach, are among the many consequences of the continuous strain on transport infrastructure and have far-reaching economic impacts. Across the aisles, policy-makers have recognized the importance of infrastructure and recently floated a new proposal of a $2 trillion dollar infrastructure-spending package that would dwarf previous investments. In light of these developments, the key questions to consider include: What are the economic benefits arising from such investments? And, to whom do these benefits accrue?

In this survey we critically review the quantitative and qualitative evidence that seeks to answer these questions. We find that the expected economic impact of transport infrastructure investment is a heavily debated subject with a longstanding history in the economic literature. Examples of early studies in this field are given by Ciriacy-Wantrup (1955); Margolis (1957), or Mohring (1961). As several previous reviews have pointed out (Gramlich, 1994; Gillen, 1996; Jiang, 2001; Bhatta and Drennan, 2003; Pereira et al., 2013), the primary points of disagreement are the quantification of economic benefits, such as the reduction in transport costs or induced rise in employment and earnings, and their potentially uneven distribution across the public. To outline our study, we begin with a review of the early literatures studying the macroeconomic productivity and labor market effects of general public capital expenditures, before providing detailed surveys of the works that investigate the direct and indirect effects of transport and seaport infrastructure investments within this broader context. Our survey of the current state of knowledge contributes
to the existing literature in several ways. First, we provide a comprehensive review of the various methodologies and empirical strategies employed in this area of research. Second, our survey offers a unique focus on the economic benefits arising from transport infrastructure, and seaport investments in particular, and documents the considerable controversy surrounding the impact of such public capital expenditures. Third, we discuss the potential causes underlying these contradictory findings and are the first to point to the insights gained from the sparse literature on the cross-border leakages from these investments. We identify this area of research as a significant gap in the current state of knowledge and a promising opportunity to reconcile the ongoing debates.

The mechanisms through which transport infrastructure investments can influence economic activity are complex and the resulting effects are often counteracting one another. On the one hand, seaport investments, for example, may enhance the productivity of domestic firms through the reduction in transport costs and improved access to domestic and international markets (Fujita and Mori, 1996). Relatedly, the resulting increase in the demand for transportation may stimulate the domestic transport and transport-related sectors (Chandra and Thompson, 2000). On the other hand, a nationally coordinated improvement of seaport infrastructure, for example, may reduce barriers to trade and worsen the exposure to international competition. The resulting increase in transportation may create a productivity-eroding congestion effect for goods- and service-producing industries that are unable to take advantage of the improved seaport services. Lastly, improvement of infrastructure may predominately serve the local markets and result in considerable reallocation of resources and redistribution of economic activity towards these communities. The resulting agglomeration effects, evidenced in port cities such as New York (Krugman, 1999), for example, create distributional challenges and contribute to the growing urban-rural divide. To complicate matters further, the distribution of potential benefits to transport infrastructure investments is not confined within national boundaries and may leak to foreign entities.

In the literature, these leakages are typically ill-defined and often treated analogously to domestic spatial spillovers. In the context of this review, we define benefit leakages as transport infrastructure investment benefits, such as seaport cost savings accruing to the suppliers of inter-
national transport services, that flow to foreign entities and are therefore removed from the overall national economic gains. Examples of such leakages include foreign shipper’s profits, foreign shareholders’ returns and/or benefits to foreign nations arising from U.S. investments in domestic infrastructure. We investigate the literature on transport investments and focus on the role of seaports, as these appear particularly susceptible to potential benefit leakages. The contributing factors to this benefit-leakage vulnerability of seaports include their role as transportation gateways that connect domestic economic activity with global markets. Indeed, the movement of U.S. imports and exports that flow by water through ports accounts for 72% percent by weight and 44 percent by value of total trade (Bureau of Transportation Statistics, 2014). This distinctive position in the overall transport infrastructure network may result in port investments accruing to foreign carriers, rather than domestic firms and/or consumers. In addition, U.S. seaports present a unique ownership structure with a mix of public and private shareholders between port authorities and terminal operators. In the case where investment cost-savings accrue to terminal operators, rather than port authorities, the economic benefits may leak overseas and cannot be realized by domestic firms and consumers via reduced transport or product prices. As public capital investment decisions are traditionally based on cost-benefit analysis (Maass, 1966), the presence of benefit leakages to foreign stakeholders can lead to chronic underinvestment in seaports.

Overall, the surveyed literature, and in particular the more recent studies (Duranton and Turner, 2012; Allen and Arkolakis, 2014; Donaldson, 2018), seem to suggest a positive economic impact of transport infrastructure investments in aggregate. Based on our review, however, we would also argue that to this date there is no consensus on the overall magnitude of the macroeconomic gains from such investments. Estimates range from moderate earnings and employment growth effects in the United States and other developed countries (Duranton and Turner, 2012; Möller and Zierer, 2018), to profound increases in output and productivity in developing countries (see, for example, Donaldson, 2018). At a more disaggregated level, we find that the volatility of earnings and employment benefit estimates depend on regional attributes, such as the industrial composition, and the specific transport infrastructure under consideration (Friedt, 2018; Monte et al., 2018).
Lastly, we review empirical findings with regard to the output, earning and employment effects of seaport investments. Specific estimates range from significantly positive to negligible and even significantly negative output elasticities with respect to the stock of seaport infrastructure, raising doubts over the national benefits of seaport investments (see, for example, Cantos et al., 2005; Melo et al., 2013; Arbués et al., 2015; Elburz et al., 2017).

Exploring potential explanations for these contradictory seaport-specific estimates, our survey indicates that the existing evidence is rather limited. Among the potential mechanisms, port investment leakages are recognized as an important source underlying the unanticipated aggregate effects (Dekker, 2005). Convincing empirical evidence, however, is limited. Simulation exercises by Dekker (2005) suggest that leakages accruing to foreign users of seaport services are nontrivial and may sway decisions against seaport investments. Evidence provided by van Exel et al. (2002) suggests international benefit leakages for the port of Rotterdam approach around 140% of domestic investment benefits. In the realm of recent European road and railway investments, Bröcker et al. (2010) show that non-investing EU member states experience cross-border benefit spillovers representing up to 55% of the overall welfare gains, while non-EU non-investing countries also experience benefit leakages that range from -1% to 28% of the overall welfare effect. In absolute terms, Bröcker et al. (2010) show that these investment leakages to non-investing EU member and non-member states translate into 342.5 million and around 270 million euros per year, respectively.

Despite this large degree of controversy and significant variation across individual studies, we are able to generalize the heterogeneous findings and summarize our literature review with the following points of emphasis:

- Public capital investments tend to have positive economic impacts on earnings and employment, but elasticity estimates vary greatly;
- Positive industry-level effects are generally concentrated in construction, manufacturing, and transport as well as transport-related sectors;
- Infrastructure investment, particularly those in transport networks, create spatial spillover effects that are of generative and redistributive nature; and
- The economic spillover effects transcend national borders and lead to significant benefit
leakages that are particularly pronounced for seaport investments.

The remainder of this review is organized into five sections. In section 2, we begin our study by clearly defining the types of benefits arising from various infrastructure investments and discussing the channels through which these benefits can arise. Given the multitude of these benefit mechanisms, we start by summarizing the aggregate effects reported in macroeconomic studies, typically employing production function approach (section 2.2). As the literature has naturally evolved from these national estimates, we survey a host of studies that contemplate geographically disaggregated infrastructure impact on regional value added and domestic spillover effects (section 2.3). Aside from the consideration of these spatially disaggregated output effects, we find that a fair amount of research also investigates the employment and earnings’ benefits arising from public capital expenditures and differentiates these effects across various industries. We summarize these distinct strands of research in sections 2.4 and 2.5.

Evolving from this literature on the various effects of broadly defined public capital expenditure, we focus our review on the more specialized empirical studies exploring the economic effects of transport infrastructure investments in general (section 3), and seaports, in particular (section 4). Within the realm of seaports, we evidence two distinct methodological approach including port impact studies heavily reliant on the input-output (I-O) technique and econometric studies employing various regression analyses. We present our findings with respect to these strands of the port literature in sections 4.1 and 4.2 and evidence a wide range of port benefit estimates. Exploring the potential mechanisms underlying this benefit uncertainty, we investigate the existing research on port-investment benefit leakages in section 5 and conclude our literature review in section 6.

2 Benefits of public capital

Economic studies analyzing the public benefits of infrastructure have a longstanding history in the academic and regulatory literatures. While regulatory research attempting to measure the economic benefits accruing from public capital typically employ narrow cost-benefit-analyses of local
projects, academic works range from macroeconomic studies estimating the influence of various types of infrastructure on aggregate output, labor, and productivity to microeconomic research exploring these responses at the urban equilibrium level of analysis. As the complexity and challenges of capturing the entire spectrum of benefits has long been recognized in the literature, each of these approaches has received considerable attention and criticism. Early research by Ciriacy-Wantrup (1955), Margolis (1957), and Maass (1966), for example, point to the shortcomings of traditional cost-benefit-analyses, whereas later studies by Holtz-Eakin (1994); Hakfoort (1996) and Gillen (1996), among others, highlight the empirical misspecifications in macroeconomic production function estimations.

2.1 Definition of benefits

Examinations of the benefits focus on three areas. These are identifying the societal benefits from public capital expenditure, estimating the contribution of infrastructure to national welfare, and determining the effect of public infrastructure spending on the distribution of income. Ciriacy-Wantrup (1955) intuitively addresses each of these points.

In his view, the benefits are multilayered and include the direct impact on economic activity, such as the positive demand shock on the construction sector or transport cost reductions valued by manufacturing firms, as well as the indirect effects spilling over across different markets and/or geographic boundaries, such as the positive demand shock experienced by the transport and transport-related service sectors. Lastly, these benefits include the “intangibles” (Ciriacy-Wantrup, 1955). While the interpretation of the direct and indirect effects is straightforward, the intangibles can be thought off as the simultaneity between infrastructure and the larger economy in which it exists. This simultaneity gives rise to a complex system in which economic agents not only receive direct benefits from cost savings and market access, for example, but also adjust their behavior in response. As Haughwout (1998) states, “in a spatial equilibrium context, the relationship between public goods and aggregate output is a combination of their productivity, their effects on local prices, and the responses of local producers and workers to local price changes.” (p. 226). Bat-
ten and Karlsson (2012) also acknowledge this feedback effect and state, “many counterintuitive outcomes between productivity and infrastructure stem from our ignorance about the complicated dynamic relationships between changes to the network itself and those occurring within the traffic using the network.”

This endogeneity dictates that the overall benefits of infrastructure depend on not only the direct user effects, but also the response of users to the availability of infrastructure. This, in turn, creates a dynamic feedback effect. Informing the analysis, Hakfoort (1996); Haughwout (1996); Eddington (2006), as well as Laird and Venables (2017) develop intuitive frameworks that break down the direct, indirect, and intangible channels of infrastructure benefits highlighted by Ciriacy-Wantrup (1955). The results are a variety of microeconomic mechanisms through which public capital can create economic benefits. While the direct effects are described as ‘user benefits’, which may include positive productivity and amenity effects, such as reductions in transportation costs and travel time, the indirect impact involves proximity effects, such as greater market access that results in investment and land use changes (Eddington, 2006; Laird and Venables, 2017). In contrast, the intangible components of the benefits to infrastructure are accounted for via employment and factor price adjustments and are best captured by an urban equilibrium model. In short, this theory suggests that household and firm location decisions adjust to the spatial variation in infrastructure and lead to the simultaneous determination of infrastructure investments and jurisdictional employment and factor prices, such as wages and land rents (Roback, 1982; Haughwout, 1996; Duranton and Turner, 2012; Alhouy and Farahani, 2017; Friedt, 2018).

2.2 Macroeconomic benefits of infrastructure

When considering the macroeconomic impact of infrastructure, the estimation of an aggregate production function that is augmented with a public capital input constitutes a natural point of departure. The resulting output elasticity with respect to general public infrastructure spending provides a benchmark for the net macroeconomic benefits of public capital including the direct, indirect and intangible effects averaged across all types of infrastructure. Although initial production
function estimations by Mera (1973) considered the regional effects of infrastructure in the case of Japan, it was not until Aschauer (1989) that this important issue gained significant popularity among the academic community. In his seminal study, Aschauer estimates an aggregate production function and reports an output elasticity with respect to infrastructure of 0.39. This particular finding drew much attention because it implied that the return on public capital is about twice as large as the return on private capital (Aschauer et al., 1990) and enough to attribute the U.S. productivity slowdown in the 1970s to the simultaneous stagnation in infrastructure spending.

Since Aschauer’s insight, the literature on the macroeconomic effects of public capital, and transportation infrastructure in particular, has taken off. Empirical scrutiny of the initial result has led to substantial controversy in the related literature and a number of output elasticity estimates ranging from Aschauer’s benchmark estimate of 0.39 to insignificant overall effects (Munnell and Cook, 1990; Munnell, 1992; Hulten and Schwab, 1991; Garcia-Mila and McGuire, 1992; Holtz-Eakin, 1994; Evans and Karras, 1994; Fernald, 1999; Pereira, 2000; Cohen and Paul, 2004; Crescenzi and Rodríguez-Pose, 2012). We present a succinct overview of this literature and the relevant output elasticity point estimates in Table 1. While the employed methodologies are similar across the highlighted studies, the reported elasticity estimates range greatly from -0.344 to 0.5. Instinctively, the explanations for the wide array of statistical results are grounded in the microeconomic mechanisms that govern the direct, indirect, and intangible effects, as well as concerns over the econometric production function specification.

Concrete criticisms have been raised by a number of authors and are summarized in Gillen (1996) as well as Button (1998). The most prominent criticisms include ad hoc modeling frameworks, such as the aggregate production function, or spurious correlations that result from the problematic time-series properties of macroeconomic data (see, for example, Pereira (2001)). Moreover, the research has been criticized for a failure to control for congestion and other negative externalities, such as air pollution, that may arise from the redistribution of economic activity and reorganization of traffic flows. Lastly, the literature has expressed concern over biased cost-benefit analyses that ignore the simultaneity of infrastructure and adjustments in logistics (Gillen, 1996),
private investment (Pereira, 2001) and labor markets (Haughwout, 1998; 2002). Overall, these criticisms and inconsistency in output elasticity estimates have cast significant doubts over the macroeconomic impact of public capital expenditure (Button, 1998).

### 2.3 Direct effects and geographic spillovers

Responding to these criticisms, the literature has turned towards more disaggregate analyses at the state, metropolitan, and county levels, both within the U.S. and abroad, differentiating between the direct local impact of public capital and its indirect peripheral spillovers. Over time, these refinements have produced a rich set of studies that disentangle the direct effects in terms local output, employment and wage changes from geographic spillover effects.

The push for more disaggregated analyses is grounded in the idea that domestic spillovers arising from public capital are more localized and may bias macroeconomic estimates leading to misinformed policy guidance (Munnell, 1992; Boarnet, 1998). A negligible estimate of the macroeconomic impact of seaports, for example, may confound a positive direct effect on the port community and offsetting negative spillovers in neighboring locales, or vice versa. Further contributing to this bias is the fact that macroeconomic studies tend to average across multiple types of public capital. Boarnet (1998), for example, points out that public capital is comprised of point and network infrastructures that vary in their respective economic footprint. The distinction is based on the services offered by a given infrastructure. Whereas a point infrastructure, such as water and sewage systems, can offer local cost savings that attract economic activity away from neighboring regions causing negative spillovers, a network infrastructure, such as roads, can reduce trade costs and increase market access for remote neighbors leading to positive spillovers and dispersion of economic activity (Boarnet, 1998).

To control for these different types of infrastructures and disentangle positive from negative spillover effects, the literature has innovated the definition of what constitutes a ‘close’ neighbor that is likely to be affected by local infrastructure investments and differentiated across various types of public capital expenditure. The most intuitive notion of ‘closeness’ is based on physical
distance or contiguity across regions, states or counties and used by a host of studies including, for example, Forkenbrock and Foster (1990); Bergman and Sun (1996); Chandra and Thompson (2000); Ozbay et al. (2007); Moreno and López-Bazo (2007); Crescenzi and Rodríguez-Pose (2012) and Arbués et al. (2015). Forkenbrock and Foster (1990) as well as Ozbay et al. (2007), for example, focus on the effects of highway capital on output and define closeness based on contiguity. Forkenbrock and Foster (1990) estimate the impact of a four-lane highway construction from St. Louis, Missouri, to St. Paul, Minnesota, on transport costs prevailing in counties contiguous to the roadway improvement and find that transport cost savings are marginal. In contrast, Ozbay et al. (2007) focus on counties located in the states of New York and New Jersey. As expected, the authors find a positive direct effect of highway capital on gross county product (GCP) and a significant reduction in GCP arising from the cumulative highway capital of neighboring counties. Moreno and López-Bazo (2007) provide very complementary evidence from manufacturing sectors located Spanish provinces. In this study, both local and transport infrastructures exhibit positive direct effects on the value added of manufacturing firms, while only transportation infrastructure causes negative spillover effects on the value added in proximate provinces.

Unlike Forkenbrock and Foster (1990) and Ozbay et al. (2007), Bergman and Sun (1996) employ a distance decay function to measure proximity. Accounting for various types of infrastructures and differentiating between urbanized and rural counties, Bergman and Sun (1996) find that only urbanized counties experience positive direct effects from local infrastructures, whereas rural-county productivity, measured by value added per manufacturing employee, varies with regional infrastructure access. Importantly, the authors find that not all types of infrastructure lead to these positive rural productivity spillovers. In fact, the results suggest that interstate highways have negative output effects in rural counties that are attributable to a drain of skilled labor and production towards more urbanized and agglomerated counties.

Boarnet (1998) is the first to deviate from geographical distance as the primary determinant of closeness and, in addition to distance, uses a host of alternative specifications that arguably affect factor mobility. The resulting estimations are based on a spatial lag model where the likeness
of counties and the ease of factor mobility are measured by spatial weights based on the relative
difference in county characteristics, such as per capita income, population density, or industrial
composition. The intuitive insight is that counties with a greater degree of similarity within this
characteristic space are more susceptible to spillover effects from infrastructure. The results are
consistent with expectations. That is, Boarnet (1998) finds a positive direct effects of public capital
on GCP and negative spillovers across counties of similar economic and demographic characteristics. In fact, the author concludes, “the evidence here suggests that negative spillovers are strongest
across similarly urbanized counties, and that similarly urbanized counties are close competitors for
mobile factors of production.” (Boarnet, 1998, p.395)

While all of these results indicate negative indirect effects arising from infrastructure in locales
of close proximity and likeness, none of the previous studies consider spillovers arising in econom-
ically integrated communities. Addressing this gap in the literature, Cohen and Paul (2004) and
Cantos et al. (2005) estimate the direct and indirect effects of infrastructure across economically
integrated regions by constructing spatial weights based on the relative level of bilateral trade. Al-
though Cohen and Paul (2004) and Cantos et al. (2005) take different empirical approaches (total
cost function vs. production function) and estimate the effects in the U.S. and Spain, respectively,
the results are quite comparable. While local motorway infrastructure reduces U.S. manufacturing
cost and increases Spanish provincial value added in the directly affected area, highway infrastruc-
ture in economically integrated locales causes positive spillovers across trade partners. Differences
in estimates across these two studies include the marginal statistical significance of the estimated
spillover effects for Cohen and Paul (2004) and the variation domestic spillovers by type of infra-
structure and industry evidenced by Cantos et al. (2005).

Recent studies, however, have reignited the debate over the effectiveness of public infra-
structure investment and cast doubts over the previous spillover estimates. Both Crescenzi and
Rodríguez-Pose (2012) and Arbués et al. (2015) find very limited evidence of spillover effects
from European infrastructure. Crescenzi and Rodríguez-Pose (2012), in fact, report that control-
lng for previously excluded determinants of economic growth, such as innovation or migration,
renders the coefficient estimates on the direct and indirect impacts of motorways within and across European regions insignificant. Similarly, Arbués et al. (2015) demonstrate that, with the exception of roads and airports, the response of output of Spanish provinces to various types of transportation infrastructures is negligible and that domestic spillover effects can only be attributed to Spanish roadways. Interestingly, the authors find that ports have a negative impact on local output. In the authors’ own words, “a plausible explanation is that whereas positive effects of new port investments could be spread across the nation, the direct and indirect costs (pollution and congestion) are assumed by the local authority and consequently by the province” (Arbués et al., 2015, p. 174). In contrast, the experience for China is markedly different. Studies by Liu et al. (2007); Zhang (2009) and Yu et al. (2013) produce evidence in support of positive direct effects of transport infrastructure and generally positive spatial spillovers at the city, regional, and national levels. Yu et al. (2013), in fact, report that spatial spillovers, unlike direct effects, increase in magnitude over the sample period from 1978 to 2009 and rival the direct effects by the end of the sample.

We summarize this literature on the direct and indirect effects of public capital in Table 2. Overall, these studies suggest a large degree of controversy concerning the net economic benefits. With the exception of the estimated domestic motorway effects, the common patterns point to negative domestic spillovers that redistribute, rather than generate, economic activity in response to infrastructure expenditures. Moreover, the surveyed research warrants caution when disentangling the economic benefits of point and network infrastructures and reveals the sensitivity of the empirical results to different types of infrastructures, industries, and spatial weight specifications, which we summarize in Table 3. As previously discussed, these spatial weights capture the likelihood of a given community being affected by an infrastructure investment elsewhere and are often based on geographic characteristics, such as a common border among localities or physical distance between them. Alternative specifications that might govern domestic investment benefit spillovers include spatial weights based on market potential as well as economic similarity and integration.
2.4 Labor market adjustments

To gain a deeper understanding of the overall macroeconomic impact on output and productivity, and to determine the innate drivers of the geographic spillover effects, another strand of the literature has developed and considers the adjustment in factor prices and labor market outcomes in response to public capital investments. Eberts (1991) and Eberts and Stone (1992) provide an intuitive discussion of the channels through which infrastructure might influence earnings and employment. The argument goes as follows. When households and firms make location decisions across a geographic region, local infrastructure acts as a major determinant of the jurisdictional amenity and competitiveness levels. Reduced transport costs and commuting times due to improved transport infrastructure, for example, enhance firm productivity and raise households’ valuation of a given location. In turn, relocating households and firms will bid up local land prices and adjust their respective wage demands and offers. Haughwout (1996) develops a tractable urban equilibrium model based on these principles.

Early studies by Carlino and Mills (1987); Deno (1988) and Munnell and Cook (1990) provide the initial empirical evidence in support of the theoretical employment effects arising from transport infrastructure. Munnell and Cook (1990), for example, estimates that a $1,000 increase in public capital per capita raises average annual employment growth by about 0.2%. The empirical analysis by Carlino and Mills (1987) suggests that doubling highway miles per square mile of land during the late 1970s would have raised total and manufacturing employment densities by 6% over the following decade. Eberts (1991) complements these findings and shows that employment growth is primarily driven by infrastructure-induced new business openings of smaller firms, particularly during recessionary periods, and that these positive employment effects are attributed to new infrastructure investments, rather than expenditures on maintenance of existing capital stock.

Building on this research, Eberts and Stone (1992) as well as Duffy-Deno and Dalenberg (1993) develop their respective empirical analyses to account for the simultaneous labor and wage adjustments in response to the provision of infrastructure. Essentially, the authors jointly estimate the labor supply and demand equations and find that infrastructure continues to exert a positive influence
on local employment. Duffy-Deno and Dalenberg (1993) provide an estimate of the employment elasticity with respect to public capital of 0.06% suggesting that a 10% increase in per capita capital stock would raise employment by 0.6%. Moreover, this study provides evidence of a negligible wage impact. In contrast, Eberts and Stone (1992) produce estimates of the statistically significant negative influence of public capital on local wages. Both of these estimated wage effects are consistent with the theoretical model and suggest that the amenity effect of infrastructure tends to be at least as significant as the productivity effect. In other words, households derive considerable value from public goods that compensates wage differentials with respect to alternative locations and tends to outweigh the upward pressure on wages due to the enhanced productivity of local firms.

Haughwout (1996; 2002) as well as Wu and Gopinath (2008) or Friedt (2018) expand upon this theory and develop an urban equilibrium model in the spirit of Roback (1982), where not only employment and wages are simultaneously determined, but other input demands and factor prices, such as land rents and domestic transport costs, play a critical role as well. Jointly estimating the system of equations, Haughwout (1996; 2002), for example, find negative, yet insignificant wage effects and statistically significant inelastic and positive public capital effects on employment and land prices that are similar in magnitude to the estimates by Duffy-Deno and Dalenberg (1993). With the exception of a positive wage effect, the results by Wu and Gopinath (2008) and Friedt (2018) are comparable to Haughwout’s findings and complementary to the findings by Dalenberg and Partridge (1997), who differentiate the impacts across industries. These results by Dalenberg and Partridge (1997) suggest that, with the exception of the manufacturing sector, U.S. highway expenditures create positive amenity effects that outweigh the enhancement of firm productivity and therefore have a negative impact on prevailing local wage rate.

While these studies have provided consistent evidence of a positive employment and negative wage effects from public capital expenditure, there exists some evidence to the contrary illustrating that public capital, and transport infrastructure in particular, may act as a substitute, rather than weak complement to labor. Berndt and Hansson (1991), for example, report negative employment effects stemming from public capital during the 1970s and mid 1980s of their Swedish sample.
from 1960-1988, whereas Dalenberg and Partridge (1995) document a similar pattern for U.S. highway and local infrastructure expenditures. Theoretically, the productivity enhancement from public capital may alter the marginal rates of return in favor of land and/or capital inputs relative to labor leading to a substitution towards these non-labor inputs. Following the theory, Nadiri and Mamuneas (1994) investigate the effects of public capital on costs as well as input demands of 12 manufacturing sectors and find significant cost reductions that coincide with a decline in labor demand; a finding that is robust to the integration of spatial spillovers (Cohen and Paul, 2004).

This early controversy over the sign of the estimated employment effects from public capital have led to a reconsideration of the previously assumed exogeneity of infrastructure and the development of more rigorous identification strategies as well as structural modeling techniques in hopes of resolving the conflicting coefficient estimates. Examples of these alternative empirical strategies include the ‘planned route IV’, ‘historical route IV’ and ‘inconsequential place’ approaches reflected in the work by Chandra and Thompson (2000); Brueckner (2003); Michaels (2008); Duranton and Turner (2012); Blonigen and Cristea (2015); Möller and Zierer (2018) as well as Heuermann and Schmieder (2018) and are clearly summarized by Redding and Turner (2015). More structural approaches exploit new developments in spatial economic modeling and include the seminal work by Allen and Arkolakis (2014) or Monte et al. (2018).

Chandra and Thompson (2000) and Michaels (2008), for example, exploit the arguably exogenous location of U.S. interstate highways with respect to rural/non-MSA counties. The authors find that the provision of highways increases earnings, employment, and retail trade in non-MSA highway counties. Brueckner (2003) and Blonigen and Cristea (2015) estimate the effect of air traffic on employment and find a consistent positive impact when controlling for the employment-air traffic simultaneity via exogenous geographic network characteristics or a quasi-natural policy experiment given by the 1978 deregulation of air traffic. In contrast, Duranton and Turner (2012); Möller and Zierer (2018), and Heuermann and Schmieder (2018) base their identification on the quasi-random variation in the interstate highway and/or rail network plans in the U.S. and Germany. As these plans were developed far in advance of the actual sample periods or without
consideration of the prevailing local economic factors, the authors argue that they render convincing instrumental variables for the existing and endogenously determined stock of public capital. The results are consistent and reflect a positive influence of transport infrastructure on employment, population, and wage growth. Duranton and Turner (2012), for example, estimate that a 10% increase in roadways leads to a 1.5% increase in employment over a 20-year period.

Similar to the work on the output and productivity effects from infrastructure, the literature on the underlying labor market and factor price adjustments has considered the potential spatial spillover effects arising from public capital expenditures. Early examples include studies by Dalenberg et al. (1998) and Chandra and Thompson (2000), who consider the employment and earnings effects of the U.S. highway system. Both studies find evidence in support of the re-distributional effects of transport infrastructure and report considerable negative employment and wage spillovers originating from locales equipped with interstate highways into the adjacent, neighboring counties. More recent work by Jiwattanakulpaisarn et al. (2009); Gómez-Antonio and Fingleton (2012) and Heuermann and Schmieder (2018) reinforces the initial evidence. While the reduction in transport costs due to the provision of highway infrastructure is found to reduce employment and wages in neighboring regions (Jiwattanakulpaisarn et al., 2009; Gómez-Antonio and Fingleton, 2012), reduced commuting times trigger a relocation of work towards more rural settings and away from urban household locations (Heuermann and Schmieder, 2018).

We present a concise summary of these findings in Table 4. For each of the reported studies, we indicate the methodological approach, type of infrastructure and time horizon under consideration, and document the geographic area of study. Given the varying methodologies and impractical comparisons of a single statistic, we offer a short summary of each paper’s primary results.

2.5 Industry-specific heterogeneity

As public capital expenditures involve a large number of infrastructures that are utilized with varying intensities across industries, the heterogeneity in industry-specific outcomes is a natural consideration. Generally, the literature distinguishes between manufacturing and service sectors and
evaluates the industry-specific heterogeneity with respect to output, productivity, and labor market outcomes. Fernald (1999) offers one of the most convincing studies differentiating the productivity effects of highway infrastructure across vehicle-intensive and non-vehicle-intensive industries. As expected, the author finds that the effects are much larger for vehicle-intensive industries able to take advantage of the publicly provided transport infrastructure. Cohen and Paul (2004) complement this finding and show that, within the manufacturing industry, production workers gain from state-wide infrastructure investments, whereas nonproduction workers are negatively affected. In a recently conducted meta-analysis, Melo et al. (2013) summarize this literature and suggest that the output elasticity estimates with respect to public capital are largest in the primary and manufacturing sectors and decrease for the construction and service industries.

In terms of the industry-specific labor market outcomes, the results tend to vary drastically across industries and types of infrastructure. The findings by Clark and Murphy (1996), for example, suggest that employment growth in the finance, insurance, and real estate (FIRE) sectors responds positively to fiscal spending, whereas other commercial sectors, such as service and trade, and industrial sectors, including manufacturing and construction, are largely unaffected. Chandra and Thompson (2000) offer convincing evidence in support of these initial findings. Focusing on highway infrastructure and averaging across direct and indirect effects, the authors show that the FIRE and transportation, warehousing, and public utilities industries experience the largest gains in earnings, whereas wages in retail trade are estimated to decline. Moreover, the authors find that export-oriented manufacturing industries exhibit positive spillover effects in adjacent non-highway counties that can be attributed to the resulting reduction in transport costs and accessibility gains.

### 2.6 Benefits of transport infrastructure investments

As evidenced by the previous summary, much of the literature on public capital expenditures rests on the effects of transport infrastructure in particular. In this section, we build on the previous discussion and expand our survey with a detailed summary of the more influential studies that bring to light new evidence on the subject of the economic impact of transport infrastructure investments.
The long-standing methodological themes include the cost-benefit analyses of isolated investment projects or computable general equilibrium models relying on the input-output tables to estimate the economic impact of these transport investments. Historic examples of such case studies are too plentiful to comprehensively review and go beyond the scope of this study. A few ‘handpicked’ studies include, for example, the analyses of the economic impacts of the M62 British motorway by Dodgson (1974), the Channel Tunnel connecting Britain and France (Vickerman, 1987; 1988), the expansion of the Chicago O’Hare airport (Brueckner, 2003), or Auckland’s Northern Motorway extension (Grimes and Liang, 2010). In contrast, Weisbrod (2008) provides an excellent review of the various I-O methodologies used to predict the effects of national, regional, state, and local transport infrastructure investment and offers insights on the potential shortcomings of these models. Moreover, Weisbrod and Reno (2009) apply the I-O methodology to estimate the economic impact of the public transportation investment and project significant increases in employment, income, and tax revenue in response to public expenditure.

More recently, widely recognized research has turned towards empirical investigations of the economic benefits derived from motorway, railroad, air- and seaport infrastructures at various levels of aggregation. Historically, the economic impact of the U.S. interstate highway system as well as other motorways has played a prominent role within this subfield. More recent work, however, has broadened the scope and explores transport infrastructure investments in developing countries, such as the ‘Golden Quadrilateral’ in India (Datta, 2012; Ghani et al., 2016; Asturias et al., 2016) or the dramatic Chinese infrastructure expansion (Banerjee et al., 2012; Faber, 2014). Throughout this section, we provide a chronological summary of the most influential studies and point to the key advances in this literature.

One of the earlier studies includes the research by Keeler and Ying (1988). In contrast to a host of cost-benefit analyses projecting the efficacy of various infrastructure investments ex ante, Keeler and Ying (1988) study the ex post economic benefits of the U.S. highway system, built between 1950 and 1973, accruing to the U.S. trucking industry. Estimating a trans-log cost function for the trucking industry, the authors find that interstate highway investments throughout the 1950s
and 1960s reduced trucking costs by almost 20% by 1973 and covered at least one-third of the original investment costs. While this finding by Keeler and Ying (1988) suggests the productive nature of the U.S. highway investments, Thompson et al. (1993) as well as Rephann and Isserman (1994) provide evidence to the contrary. Developing an empirical strategy similar to Chandra and Thompson (2000) and Rephann and Isserman (1994), for example, investigate the impact of U.S. highway construction across counties directly linked to the instate highway network and those in close proximity. The authors’ findings indicate that highway construction does not create a local boom in general and that only those counties in proximity to metropolitan areas or some degree of prior urbanization reap the long-run benefits from these infrastructure investments, in part due to the decentralization from a nearby city.

This reorganization and decentralization of intra-city production, employment, and population in response to the construction of highway infrastructure is echoed through the U.S. based findings by Thompson et al. (1993) and Baum-Snow (2007), Spain-based results by Garcia-López et al. (2015) and China-based findings by Baum-Snow et al. (2017). In the case of Portugal, Pereira and Andraz (2006) investigate these domestic spillover effects from transport infrastructure investment at a more aggregated regional level and find significant evidence in favor of regional agglomeration, rather than decentralization. The authors demonstrate that regional spillover effects outweigh direct effects for more centrally located, interior regions, whereas peripheral regions benefit most from the direct effects of these investments. Pereira and Andraz (2006) measure these benefits in terms of infrastructure-investment-induced changes in private investment, employment, and regional private output. The authors’ long-run analysis, based on a vector autoregressive model, suggests that centrally located regions and Lisbon in particular, capture the majority of these transport investment benefits. These long-run regional effects for Portugal stand at odds with the decentralization hypothesis supported by the aforementioned studies.

Berechman et al. (2006) reconcile these conflicting domestic spillover estimates using an extended production function approach that controls for spatial and time lags in terms of transport infrastructure investment. Based on this model, the authors show that the economic impact of U.S.
interstate highways on gross state, county and municipal product declines with the disaggregation of the geographic units. The authors identify intensifying geographic spillovers at more disaggregated levels of analysis as the root cause for this decline. Equally important, the authors show that the direct effects of U.S. highways on gross state, county or municipal product follow an inverse U-shape with respect to the preexisting highway stock. That is, states with minor highway capital experience no economic effects from highway investments, whereas states with intermediate highway stock reap the largest investment benefits when compared to the declining impact for ‘congested’ states with a significant preexisting interstate highway network.

Aside from these studies set in the context of the U.S. and other developed nations, recent research on the economic impact of transport infrastructure investment in developing countries has made critical contributions to this field of study. Focusing on the effect of railroads in India, seminal work by Donaldson (2018) shows that access to railroads increases agricultural income by about 17%, equivalent to about 40 years of economic growth in India between 1870 and 1930. For the more recent Indian history, Datta (2012) shows that the construction of the ‘Golden Quadrilateral’ (GQ), a 5800 kilometer (km) highway system connecting four major metropolitan areas in India, is associated with a significant reduction in the perception of transport as a major obstacle to production. Using World Bank survey data and a difference-in-differences methodology, Datta (2012) further estimates that firms in treated cities with new access to the GQ reduce inventory and are more likely to switch suppliers than firms in the control group unaffected by the construction of the GQ. Findings by Asturias et al. (2016) complement Datta’s research and estimate that the GQ and the associated reductions in transport costs has increased aggregate income by 2.71% or roughly $4.1 billion per year. Investigating the transport-related mechanisms of this income growth, the authors demonstrate that allocative efficiency is an important determinant explaining up to 19% of overall gains for some states.

In the case of China, Banerjee et al. (2012) find that a 10% increase in distance to road or railway infrastructure, instrumented for via a hypothetical network, reduces Chinese county-level income by around 7% during their 18-year sample period from 1986 to 2003. Moreover, the au-
thors find that this effect is largely generative, rather than a redistribution of economic activity from more distant counties. Separately identifying the effects of land, air, and water transport infrastructure on regional Chinese economic development, Hong et al. (2011) produce consistent evidence that suggests that land and water infrastructure are the principal determinants of economic growth, while air transport infrastructure seems less relevant. Faber (2014) provides direct evidence to the contrary of Banerjee et al. (2012) and Hong et al. (2011) suggesting that rural Chinese counties experience a significant decline in industrial and total GDP in response to an improved connection to the trunk highway system. Faber’s results point to the redistribution of economic activity, rather than new generation through highway investments in China.

Considering Sub-Saharan Africa, Storeygard (2016) illustrates that motorway network distance has a significant impact on economic activity. To identify economic activity when direct estimates of GDP at the MSA level are unavailable, the author takes a novel approach and relies on the ‘lights at night data’. Moreover, Storeygard (2016) uses variation in global oil prices interacted with road network distance to approximate temporal changes in transport costs. The author estimates that a 1% increase in transport costs reduces urban light intensity by 0.28% in cities at a distance of 500 km from a Sub-Saharan African port-city and that urban areas in closer proximity to seaports are much more resilient to changes in global oil prices.

While each of these studies has advanced our understanding of the economic impact of transport infrastructure investments on a geographically dispersed set of countries with varying levels of prior development, we note that relatively few studies explicitly account for the associated externalities of these investments. Examples of these side effects to public capital expenditures include issues of congestion, infrastructure damages, and air pollution due to greater rates of utilization (Winston, 1991; De Borger et al., 2008; Redding and Turner, 2015). Duranton and Turner (2011) provide direct evidence of the congestion externality and coin the ‘fundamental law of road congestion’, which suggests that a 1% increase in roadway infrastructure raises congestion by 1% in response. Both Winston (1991) and De Borger et al. (2008) make the argument that these negative externalities of transport infrastructure investment are significant and can be internalized via effi-
cient infrastructure pricing strategies. To implement optimal pricing strategies, however, further research should clearly delineate the direct investment effects from these externalities and quantify the potential public burdens that should be internalized.

Moreover, with the exceptions of the aforementioned research by Pereira and various co-authors, the previous research has produced comparatively little evidence on the dynamics of the economic impact of transport infrastructure investments or deeply considered the potentially decreasing returns to scale deriving from these public capital expenditures. A second highway network, for example, duplicated the existing public capital stock would not be expected to have the same benefits as the first. To this date, we observe a significant lack of evidence concerning the rate at which economic benefits of transport infrastructure investments diminish. Yet, from a policy perspective, this statistic is a critical element in forecasting the anticipated economic impact of any transport infrastructure investment expanding upon the existing capital stock and particularly relevant in the developed country case.

2.7 Benefits of port investments

As evidenced by the previous review of studies investigating transport infrastructure benefits, motorways play a predominant role and have received most of the academic and political attention. The economic impact of seaport expenditures, on the other hand, is a more specialized topic, but one with particularly relevant implications. In todays urbanized economies, most centers of economic activity are port-cities critically dependent on the performance of this particular transport infrastructure (Acemoglu et al., 2005). Given the unique position of seaports within the transportation network and their distinctive characteristics, however, it is important not to extrapolate the previously discussed findings concerning the benefits of other types of transport infrastructure on seaports. With a unique governance structure that combines public and private ownership, for example, joint investment decisions must find hybrid solutions that consider private concerns of efficiency and profitability, as well as public interests of socially desirable outcomes (Musso et al., 2006). Moreover, ports represent central nodes in the global supply chain network that act
as important gateways connecting a multitude of domestic and foreign markets (Notteboom and Rodrigue, 2005), but can also create important bottlenecks in these systems.

As international transactions and intermodal cargo shipments continue to grow, policy-makers recognize this essential position of ports in the supply chain network and consider the investment risks and opportunities associated with this rapidly growing transport sector. The statistics published in the Maritime Administration’s (MARAD) U.S. Public Port Development and Expenditure Report, for example, reveal that between 1946 and 2006 over $30 billion have been invested into capital improvements to U.S. port infrastructures (MARAD 2009). Since then, MARAD has initiated the Strong-Ports Program to support further capital expenditures across the U.S. seaport network consisting of over 300 points of entry and exit. In the face of rapid container shipping consolidation, where the top ten global shipping lines now hold over 80% market share, and continuous technological innovation in the transport sector, such as the 2016 expansion of the Panama Canal and exponential growth of container vessels, however, industry experts argue that the current level of U.S. public port investments falls short by about $100 billion of the required expenditure to maintain the future competitiveness of U.S. firms engaged in global markets.

Similar to other transport infrastructure investments, the key questions consider the evaluation of the potential benefits derived from public seaport expenditures as well as the distribution of these gains across national, but also foreign stakeholders. To shed light on the answers to these important questions and highlight the lessons learned from the existing research on this unique transport infrastructure, we focus in this section on the port-related literature. Based on our findings, we divide the reviewed studies into two camps and categorize them as either port economic impact studies (section 4.1), or econometric port analyses (section 4.2).

2.8 Economic impact studies

Traditionally, the benefits of seaport infrastructure investments have been informed by economic impact studies, which have a long-standing history in the academic and primarily regulatory literature. In fact, the popularity of these impact studies has led to the development of an official
regional port economic impact kit first published by MARAD in 1979 and subsequently updated until 2000. Identifying the economic footprint of a variety of existing seaports in terms of output, income, employment and value-added, these studies are used to evaluate the anticipated effects from further investment and justify public expenditures. Waters (1977); Kaufmann (1979) and Davis (1983) provide three of the earliest reviews of this literature and identify over 20 unique impact studies conducted between 1961 and 1982. Dooms et al. (2015) offer a more recent survey of this research comprised of 33 impact studies. A comparison of methodologies suggests that most of the early studies relied on economic base models based on expenditure surveys of port industries and the application of Keynesian multipliers, whereas more recent work has refined and employed I-O analyses and computable general equilibrium models (Waters, 1977; Davis, 1983; Benacchio and Musso, 2001; Dooms et al., 2015). The common goals underlying these impact studies are to identify the direct impact on the surveyed port industry and measure the indirect or catalytic effects resulting from the inter-industry linkages between the port industry and other goods- and service-producing sectors.

Our review of the subsequent literature on this topic reveals the critical influence of these early impact studies regarding the definition and evaluation of the benefits from seaport investments. A common theme throughout this field of study suggests that the economic benefits of seaports can be summarized into three primary categories including

1. the **direct impact** on the port industries,

2. the **indirect effects** on port-related industries and

3. the **induced impact** on port-dependent industries,

which mirrors the aforementioned compartmentalization of the broader public capital benefits developed by Ciriacy-Wantrup (1955). Yochum and Agarwal (1987), for example, define the direct benefits of the provision of a seaport as the economic impact on ‘port-attracted’ firms, such as freight forwarders, rail and truck transport, terminal operations, vessel supply, or pilotage, which would be forgone in the absence of the port. In contrast, the authors characterize the induced
benefits as the economic impact on port-dependent industries that gain from greater international market access and reduced transport costs for exported outputs and/or imported inputs. Applying these concepts to the Port of Hampton Roads, Virginia, the authors find that the port creates 74,000 jobs, $1.37 billion in earnings, and 159.9 million in tax revenue in the Commonwealth of Virginia. DeSalvo (1994); Toh et al. (1995) and Acciaro (2008) add to this discussion defining the indirect and induced impacts as the multiplier mechanism that hinges on the inter-industry linkages determining the effects of successive rounds of expenditure. However, these authors also note that greater accessibility invites import competition that may leak some of the port benefits to foreign entities and diminishes the direct effects of a port. As discussed below, these benefit leakages create a disconnect between the globally optimal level of seaport investment and domestic seaport policy, solely based on the national gains from investment.

The estimated port-specific impacts vary widely across the related studies. While Gripaios and Gripaios (1995), for example, report a mild effect of the Port of Plymouth on the local British economy that accounts for around 0.2% of local employment and around 0.8% of sub-regional GDP, Toh et al. (1995) estimates an economically significant effect for the Port of Singapore suggesting that one million dollars of additional port revenue create an additional $760,000 of output and add about 20 new jobs to the local Singaporean economy. In contrast, Yochum and Agarwal (1987) investigate the Port of Hampton Roads, Virginia and estimate that the port creates around 74,000 jobs in port and port-dependent industries throughout the Commonwealth of Virginia.

The considerable variability in impact estimates is one of the main criticisms against these economic impact studies and is commonly attributed to the variation in the size and economic significance of the ports under consideration, as well as the methodologies employed. The key consideration is the definition of the port impact area (Notteboom and Rodrigue, 2005) and the extent of induced benefits, which vary greatly across the respective methodologies. Similar to Waters (1977) and Davis (1983), Castro and Millán (1998) provide an updated overview and comparison across these methodologies and categorize them into four different approaches including the previously discussed economic base approach used by Gripaios and Gripaios (1995), the Keynesian
income-expenditure multiplier model, and the input-output methodology employed by Yochum and Agarwal (1987) as well as Toh et al. (1995). In addition, the authors discuss the ‘models of port demand’ pioneered by DeSalvo (1994) and DeSalvo and Fuller (1988; 1995). Based on this model comparison, Castro and Millán (1998) conclude that the I-O methodology strikes the most favorable balance between the evaluation of direct, indirect, and induced seaport benefits and apply it to the Port of Santander, Spain. The results suggest that the Port of Santander is an important driver of the local economy and creates between 17% and 18% of regional employment that is primarily driven by the induced impact of the port (around 15 to 16 percentage points).

Despite the intuitive notions underlying each of these methodologies and their continued application in the more recent literature, these early considerations are subject to numerous critiques. Waters (1977), Davis (1983), and Musso et al. (2000), for example, offer an extensive list of potential shortcomings that apply even in today’s context. One of the primary criticisms is the inaccuracy of expenditure surveys and the implied port-dependencies across industries. Due to a significant lack of local industry data, most port impact studies are forced to rely on expenditure surveys to gather information on port-related economic activities. The central issues addressed by these surveys are industry-specific statistics regarding output, employment and wage rates, and how much of this activity is attributable to the local seaport. With response rates as low as 10% (Santos et al. 2018), however, many studies have to rely on the conjecture of industry-specific dependencies on a given port. Naturally, the mismeasurement of these relationships can introduce substantial bias in the overall economic impact estimates.

Waters (1977), Davis (1983), and Musso et al. (2000) further point to the rigidity of Keynesian multipliers and I-O tables as a major criticism that continues to plague port impact studies today. As production and transportation technologies evolve, the assumed port-dependencies may vary not only across industries (Waters 1977), but also over space (Musso et al., 2000) and time (Davis, 1983). The original port-city model, for example, was developed on the premise that the provision of seaport infrastructure creates a comparative advantage that drives the agglomeration of the local economy within the port area (Fujita and Mori, 1996). Given historically high transport costs and
the ‘lock-in’ effect of economies of scale (Fujita and Mori, 1996), the geographic port impact area had a comparative advantage in terms of market access and transport costs and was rather narrowly defined. Changing technologies, such as the introduction of the container and intermodal transportation, however, have altered this landscape, diluted the local impact and extended the geographic influence of port infrastructure. Nowadays, the emergence of load center networks causes an even wider spatial distribution of port-related activities that reach far beyond the local port system (Notteboom and Rodrigue, 2005). Naturally, this development has drastically changed port dependencies across space as well as time and is reflected in the declining estimates of the direct impact of a port as well as the rise of the induced effects on regionally distributed port-dependent industries evidenced by the chronological progression of the literature (i.e. contrast findings by Yochum and Agarwal (1987), Castro and Millán (1998), and Santos et al. (2018)).

Lastly, port impact studies tend to evaluate and compare the benefits of an existing seaport against the extreme counterfactual that would arise in its absence. The resulting impact approximations must be interpreted with care. The estimates do not represent elasticities of output, employment or factor prices with respect to port services and fail to shed light on the marginal effect of an investment-induced change in maritime traffic. Instead, the results indicate the average response of the local economy to having access to a seaport that is based on average, rather than marginal, inter-industry relationships (Davis, 1983). Failure to recognize this important nuance can lead to significant misjudgment of the anticipated effects from port infrastructure investments.

Despite these fundamental shortcomings, the I-O model continuous to be employed throughout the more recent literature on the economic impacts of ports. Studies by Jung (2011), Acosta et al. (2011) and Artal-Tur et al. (2016), for example, evaluate the economic impacts of the Ports of Busan located in Korea, and Tarifa as well as Cartagena situated in Spain, using a refined regional I-O technique that adjusts the national input-output table for local idiosyncrasies in port-dependencies. The authors tend to claim that the amended I-O methodology strikes the most reasonable balance between the detailed microeconomic impacts on the directly affected port industries and the resulting macroeconomic spillovers into the port-dependent regional economy. Santos et al. (2018)
further adapt this regional I-O model and include national and regional statistics to circumvent persistent survey data limitations and provide a more accurate definition of the expanding port impact area. Based on these model adaptations, the estimated total employment impacts, for example, vary from 746 jobs attributed to the Port of Tarifa (Acosta et al., 2011) to 117,136 jobs attributed to the port of Lisbon, Portugal (Santos et al 2018). While these amendments have partially addressed the issue of rigidity in I-O tables and refined our understanding of the geographic distribution of the economic impact of a port, the apparent lack of cohesion has exacerbated concerns of external validity and casts doubts over the general conclusions that can be drawn from these studies.

2.9 Econometric analyses

The inability to adjust port-dependencies over time, lack of cohesion of findings across impact studies, challenges of defining the proper port impact area, and limitations regarding insights on the marginal effects of changes in seaport services continue to restrict I-O analyses. In response to these persistent criticisms, a number of studies have moved away from the I-O analysis and explored alternative empirical strategies to evaluate the economic impact of a port. While the empirical methodologies and port areas in these studies continue to vary greatly, the econometric analyses tend to produce employment and/or output elasticities with respect to port investments and port throughput that ease the comparison of the economic impacts across ports and improve policy guidance. In general, the literature suggests economically and statistically significant direct employment effects, mixed responses in output, and considerable domestic spillovers arising from port investments and port services.

Early examples of this parallel strand of literature on the economic impact of seaports include studies by Musso et al. (2000) and Acciaro (2008), who develop and employ a model that is based on location coefficients. These coefficients determine an industry’s probability of port-dependency via a comparison of location quotients across port and non-port areas. Musso et al. (2000) and Acciaro (2008) find evidence in support of a significant increase in employment ranging from 8% to 20% of all municipal jobs resulting from the ports of Sardinia and Geneo, respectively.
Alternative empirical approaches to evaluate the changes in employment outcomes in response to maritime traffic include the Generalized Method of Moments system estimator developed by Blundell and Bond (1998) employed by Bottasso et al. (2013), an autoregressive model (Seo and Park, 2018), and a two-step Tobit procedure to circumvent sample selection bias among port provinces (Ferrari et al., 2010) or an IV approach to circumvent the endogeneity of seaport services and local employment (Friedt, 2018). Despite these differences in econometric specification, the findings are generalizable. Port services stimulate regional employment. Within Europe, a 1% rise in maritime traffic increases service sector employment by 0.02% (Ferrari et al., 2010). Bottasso et al. (2013) find that a one million ton increase in port throughput raises European regional employment by 0.0006%. Seo and Park (2018) estimate that South Korean port services significantly reduce regional unemployment relative to the national level, while Friedt (2018) produces evidence that a 1% increase in U.S. port service raises county-level employment by about 0.06%.

In terms of output, the results vary by geographic region as well as methodology. Whereas studies focused on the economic impact of Asian ports consistently document an economically and statistically significant influence of ports on regional output, the output effects of European ports are more controversial and sensitive to sample selection and econometric specification. A spatial econometric panel data analysis on 621 European regions presented by Bottasso et al. (2014), for example, suggests that a 10% increase in port throughput raises regional GDP by 0.03%. In contrast, a similar spatial econometric analysis on 47 Spanish provinces by Arbués et al. (2015) produces evidence of negative direct output effect arising from port infrastructure. In the case of Germany, a panel data analysis by Breidenbach and Mitze (2016) produces negligible port effects on regional GDP per capita when controlling for the potential endogeneity of maritime traffic via an instrumental variables’ technique that exploits exogenous variation in historic port locations.

Evidence on the economic impact arising from Asian ports provides a more positive outlook on port investments. Song and Van Geenhuizen (2014) as well as Shan et al. (2014) investigate the role of seaports in the Chinese economic development. Ports are found to stimulate output and output growth. Estimates suggest that a 1% increase in port infrastructure, for example, raises
average Chinese regional output by 0.13% to 0.19% (Song and Van Geenhuizen, 2014), whereas a 1% increase in Chinese port throughput raises local port-city output per capita growth by 0.76 percentage points (Shan et al., 2014). The former results, however, are subject to significant heterogeneity across Chinese regions with elasticity estimates ranging from 0.09% for the Central Chinese region to 1.43% for the Yangtze River Delta. Estimated Korean port effects are roughly consistent with this evidence from China. South Korean ports boost regional output growth, but only for the largest ports in terms of bulk cargo and container throughput (Park and Seo, 2016).

The controversy over these diverging estimates in output outcomes in response to European, Chinese and Korean port investments have multiple explanations that are well-grounded in the New Economic Geography (NEG) theory and supported by recent trends in the maritime transport sector. Intuitively, the NEG theory suggests that port-driven transport costs play a critical role in the determination of competing agglomeration and dispersion forces that influence the location of economic activity (Fujita and Mori, 1996; Fujita and Thisse, 2006). Naturally, traffic demand and infrastructure expenditure are subject to this geographic distribution of economic activity leading to the simultaneous determination of urban development and infrastructure investments and services (Fujita and Mori, 1996; Fujita and Thisse, 2006). Subject to this endogeneity, traditional empirical analyses of various transport infrastructure investments tend to be biased and require innovative strategies to properly identify their true economic impacts (Fernald, 1999; Chandra and Thompson, 2000; Duranton and Turner, 2012; Breidenbach and Mitze, 2016; Friedt, 2018).

In addition, the NEG theory demonstrates that a port-induced reduction in transport costs and the ensuing redistribution of economic activity may disperse port investment benefits across a wider geographic region (Fujita and Mori, 1996; Fujita and Thisse, 2006). Eroding the local economic impact, it is challenging to empirically identify the port effects at the proper level of geographic disaggregation. This, of course, is a familiar issue in the literature on port impacts and revitalizes one of the original criticisms that censures the ill definition of port impact areas (Davis, 1983; Ducruet and Notteboom, 2012).

Recently, however, the difficulty of defining the proper impact area has been exacerbated by
several developments in the maritime transport and port industries. In addition to the concerns over the endogeneity infrastructure investments and the peripheral redistribution of port-induced economic activity, the port integration in global value chains (Robinson 2002) and regionalization and de-maritimization of ports has seen a relocation of direct port activity towards the hinterland (Notteboom and Rodrigue, 2005). Nowadays, vast distribution networks reap significant benefits from increasing port investments and services, so that the “external spill-over effects of ports are expanding from the local port system towards a much larger international economic system. As such, the regionalization phase enhances a situation where port benefits are likely to ‘leak’ to users in inland locations” (Notteboom and Rodrigue, 2005, p.17) making it challenging to estimate the true impact of seaport investments. The containerization of international cargo and other innovations in intermodal transport magnify these developments (Ducruet and Notteboom, 2012). As the facilitation of containerized cargo is more capital-intensive than traditional modes of maritime shipping and ports transform into transshipment hubs, rather than ports of final destination, the benefits of port investments evaporate from the local port industry and shift towards the end users of containerized cargo enjoying cost savings from the reduction in freight rates (Cohen and Monaco, 2008).

Due to reduction in transport costs, these beneficiaries are likely to be located at great distances from the original seaport of entry or exit. Empirically, this dispersion of benefits manifests itself in considerable spatial output and employment spillover effects arising from seaport activity that tend to exceed the direct local impacts (Castro and Millán, 1998; Cohen and Monaco, 2008; Bottasso et al., 2014; Song and Van Geenhuizen, 2014; Fageda and Gonzalez-Aregall, 2017). Across Europe, Bottasso et al. (2014), for example, find that a 10% increase in port throughput raises GDP in proximate regions by 0.17%, relative to the previously indicated 0.03% in the home region.

We provide a condensed overview of this literature in Table 5. Similar to the previous summaries, we differentiate studies by methodology, type of infrastructure, time horizon under consideration and geographic area of study. Moreover, we document whether the researchers consider the presence of domestic spatial spillovers in their analyses and offer a brief description of the primary
findings, rather than a single statistic that cannot be compared across studies.

3 Leakages

From a regulatory perspective, the distribution of these port investment benefits is critical to the investment decision-making process. When the costs of congestion and environmental pollution, for example, are borne by local port municipalities, while benefits are enjoyed across the larger, perhaps global, economy, cost-benefit analyses may be unfavorable and the national infrastructure network may suffer from chronic underinvestment. As a result, the governance over port activities and funding decisions for further port investments are guided by a complex set of competing municipal, regional, and national interests that are difficult to align (Merk et al., 2013).

In addition to these distributional challenges at the domestic level, port and other transport investments create geographic benefit spillovers that are not confined within national boundaries. Examples of international benefit leakages are plentiful and perhaps most pronounced across well-integrated countries, such as the members of the European Union. Baird (2004), for example, claims that the value added of a given seaport tends to be based on a narrowly defined geographic area, while investment benefits are bound to leak across international borders. In the case of Germany, Baird cites that in 2001 about 44% of all container traffic handled by the ports of Hamburg and Bremerhaven were transshipments with international final destinations. The author concludes “any cost-benefit analysis that considers only the local, or national impacts should be regarded as insufficient [...] (and) should have their impacts evaluated across the region as a whole.” (p. 389)

Similarly, in an OECD report on the competitiveness of Rotterdam and Amsterdam in the global environment of port-cities, Merk et al. (2013) remark that “Rotterdam and Amsterdam can be considered ports that have significance for the whole of Europe. [...] Most of their hinterlands are located outside the Netherlands, with Rotterdam being the main port for large parts of Germany, as well as a major port for Central Europe and Eastern Europe, Switzerland and northern Italy. Exporting and importing firms in these regions benefit from the efficient operations of both the port
of Rotterdam and Amsterdam.” (p.9) As such, port investments are becoming a matter of international concern, where the distribution of investment benefits across national and international stakeholders must be weighed against the domestic opportunity costs of such public expenditures. Musso et al. (2006) note that in response to these complexities there is a trend towards greater private funding of port investments, in part because public port investments have not yielded the societal benefits originally anticipated.

While many of these studies enhance our understanding of the true geographic dispersion of economic impacts derived from seaports and other transport infrastructures, they have largely failed to differentiate between regional and cross-country spillovers or distinguish between domestic and foreign beneficiaries. In fact, throughout our review of the vast literature on the economic impact of various public capital expenditures and growing research on spatial spillovers, we find that the consideration of benefit leakages to foreign stakeholders has played a very limited role. Laird et al. (2005) summarize part of this literature and conclude, “at this time there is no definitive modelling system that captures all network effects, so the full scale of the economic impact of a project when price does not equal marginal social costs is not yet fully resolved” (p. 543). Addressing this concern and major gap in the literature, our review of the more recent research suggests that there are a handful of studies that make note of the possibility of cross-border benefit leakages and quantify these international benefit spillovers. The analysis and review of this specific literature, however, is complicated by the fact that the definition of what constitutes benefit leakages varies greatly across this sparse set of research.

In one of the earliest studies acknowledging the possibility of investment benefit leakages, Margolis (1957), for example, equates leakages with lost benefits due to greater import competition. In contrast, Goss (1990), Munnell (1992), and Chandra and Thompson (2000) vaguely define investment leakages as mere spatial benefit spillovers that accrue to economic agents located in non-investment areas. Similarly, Rephann and Isserman (1994) refer to these benefit spillovers as interregional leakages. While each of these studies and others have advanced our understanding of the geographic distribution of public investment benefits, none of these studies clearly differenti-
ates between national and international spillovers and pinpoints cross-border benefit leakages.

A more careful definition of investment benefit leakages separates domestic spatial benefit spillovers from international ones and isolates the focus on the latter. To reiterate, we define ‘investment benefit leakages’ as transportation cost savings from transport infrastructure investments that are removed from the overall national economic benefits via foreign shipper’s profits, foreign shareholders’ returns and/or benefits to foreign nations. This definition corresponds with the elaborations by Notteboom and Rodrigue (2005), who describe benefit leakages as “the external spill-over effects of ports [that] are expanding from the local port system towards a much larger international economic system. As such, the regionalization phase enhances a situation where port benefits are likely to ‘leak’ to users in inland locations” (p. 17).

There are several mechanisms that contribute to the wide distribution of seaport investment benefits and drive potential benefit leakages overseas. First, seaport investments and the resulting cost savings might accrue to international shippers who face limited competitive pressure to pass these savings on to domestic consumers or exporters in the form of lower transport costs (Dekker, 2005). In reality, however, this mechanism may be insignificant, as international carriers tend to operate in a highly competitive market space struggling to earn positive profits. Evidence of this competitiveness is given by the recent bankruptcy of major South Korean shipping line, Hanjin.10

If international and domestic carriers, indeed, pass on port cost savings through a reduction in transport costs, investment benefits may still leak to international stakeholders through five primary channels highlighted in the previous literature. First, given the widening of the port impact area, there is a disconnect between the local costs of a port and the local versus far spread benefits of port investment. Benacchio and Musso (2001) argue that “port services show a decreasing payback of labour and an increasing return on capital investment. While the former is located within the local economy, the latter [...] seldom comes either from the local economy or even from the country itself” (p. 27). As such, the additional return on capital through port investments is likely to leak across borders to foreign capital owners. Given the prevalence of vertical integration, which leads to the international ownership of firms, this global distribution of benefits from local port
investments is becoming increasingly likely.

Second, a reduction in port costs typically reduce shipping rates on the entire round trip of international carriers. As such, not only the share of domestic products on a given round trip experience a reduction in trade costs, but also the share of international goods (Laing, 1977; Friedt and Wilson, 2019). Thirdly, publicly traded domestic exporters benefitting from transport cost reductions may be partially owned by foreign shareholders earning higher returns in response to the seaport investment. Fourthly, the reduction in transport cost not only creates greater access for domestic firms in international markets, but also raises competitive pressures for these and other domestic firms through foreign import competition. Margolis (1957) raises this concern in the context of transport infrastructure investments and a number of international trade theories highlight this mechanism through a more broadly defined reduction in international trade costs (see, for example, Krugman (1980) or Melitz (2003)).

Lastly, the domestic distribution of internationally traded products may be facilitated by international intermediaries. Even if seaport investments lead to transport cost reductions and domestic shareholders holistically own domestic exporters, international intermediaries may capture the cost savings from reduced transport costs and do not extend price reductions to final domestic consumers or exporters. Recent work by Atkin and Donaldson (2015) provides considerable evidence in support of this hypothesis. Estimating the effects of reductions in international trade barriers on final goods’ prices in Ethiopia and Nigeria relative to the United States, the authors find that consumers in remote locations of these developing countries experience very small price reductions, while most of the gains accrue to intermediaries. Of course, these findings are based on developing countries and contrasted to the U.S. experience.

Direct empirical evidence of the benefit leakages from seaport or more broadly defined transport infrastructure investments is surprisingly sparse and the differentiation of the underlying mechanisms driving these leakages is virtually non-existent. Moreover, the few estimates we evidence are based on varying empirical methodologies and exclusively centered on European investments, such as the Trans-European Transport Network (TEN-T) projects, whose hall mark
is a transnational investment approach. To the best of our knowledge, the first of these estimates are presented by van Exel et al. (2002), who emphasize the importance of taking account of the cross-border network effects and European Value Added in the evaluation of supranational infrastructure investments. The authors exemplify the merit of their methodology through three previously conducted TEN-T impact studies. For these projects, the estimates suggest that transport infrastructure benefits, evaluated from a supranational perspective, exceed national estimates by 25% for a high-speed rail network connecting Paris-Brussels-Köln-Amsterdam-London, 50% for a rail link between the ports of Rotterdam (Netherlands) and Antwerp (Belgium), and 140% in the case of an expansion of the port of Rotterdam. van Exel et al. (2002) base these estimates on European Value Added (EVA) calculations. According to the authors, EVA is comprised of multiple criteria, including for example transport efficiency, social cohesion and economic development, among others. Calculations, however, are solely based on the criteria that can be monetarized, such as strategic mobility, which is a function of population weighted travel times and GDP weighted travel costs, or economic development, measured in GDP growth rate changes.

Gutiérrez et al. (2011) also focus on one of the TEN-T projects, but take a different approach methodologically. In their study, the authors gage the benefit leakages to the construction of the motorway from Gdansk to Vienna (in the west) and Bratislava (in the east) via a novel accessibility indicator, which measures the accessibility improvements due to the highway investment in highway and non-highway regions. Unlike Chandra and Thompson (2000) and others, however, the authors argue that it is necessary to differentiate benefit spillovers between those which are of fundamentally national interest and those which are of international interest. Defining regions affected by the motorway at the European NUTS 3 level, Gutiérrez et al. (2011) find significant benefit leakages, in terms of accessibility improvements, outside of the national borders ranging from 1.4% to 35.9% of national gains depending on the motorway segment under consideration. Intuitively, motorway sections closer to the borders produce greater accessibility gains and potential benefit leakages than interior infrastructure investments.

In the case of Spain, Lopez et al. (2009) investigate the domestic and international effects of
the Spanish Strategic Transport Infrastructure Plan (PEIT) implemented from 2005 to 2020. The specifics of this transport investment plan involve the construction of around 5000km of high capacity roads (HCR) and 6000km of high-speed rail (HSR). Similar to Gutiérrez et al. (2011), the authors measure cross-border effects via an accessibility indicator and find economically significant gains domestically and in the neighboring countries of France and Portugal. Specifically, the network efficiency accessibility indicator measures the accessibility of node \( i \) as the travel time between node \( i \) and any node \( j \) on the actual transport network, relative to the ideal (as the crow flies) travel time between these two nodes. This efficiency measure is weighted by the population of region \( j \) and divided by total population spread across the entire network. Cross-border accessibility gains, or benefit leakages, are measured as the percentage change in the network efficiency accessibility indicator for international regions in France and Portugal and range from 1.15% to 4.10% for Portugal for the HCR investments. For France, these cross-border gains range from 0.45% to 2.60% and average 1.48% resulting from the improved road network. The population weighted average cross-border benefit leakages amount to 1.80%, which in comparison to the roadway accessibility gains for Spain (2.6%), are very significant.

In the case of rail, Lopez et al. (2009) find that the cross-border accessibility gains are much larger and average 17.23% for Portugal and 23.51% for France. The population weighted average cross-border benefit leakages, measured in terms of the network efficiency accessibility gain, from HSR are 20.21% and considerable given the average domestic gains of 34.52% for Spain. Based on our own calculations in terms of leakages, Lopez and co-authors’ estimates suggest that 37% of the total rail and 41% of the total road investment benefits accrue outside of Spain to the neighboring regions of France and Portugal.

The most comprehensive study of European transport investment benefit leakages was done by Bröcker et al. (2010), who develop a Spatial Computable General Equilibrium (SCGE) framework and apply the model to a list of 22 high priority road and railway projects under the TEN-T initiative. According to the authors, SCGE models have several advantages including a relaxation of the perfect competition assumption underlying cost-benefit analysis and the ability to simulate di-
rect and indirect economic impacts under several competing policy alternatives. Most importantly the SCGE model accounts for domestic and international distribution of transport infrastructure benefits. On the downside, however, the model imposes restrictive factor immobility, which suppresses the agglomeration forces often described in the aforementioned NEG literature (see, for example, Fujita and Mori (1996)) and factor price adjustments in response to infrastructure investment (Haughwout, 1996; 2002; Friedt, 2018). Based on the simulations comparing the status-quo scenario to the fully funded and implemented TEN-T project under consideration, Bröcker et al. (2010) find varying rates of return on investment and significant EU and non-EU benefit leakages.

Domestically, the investing countries capture 40% to 105% of the total welfare gains from TEN-T investment projects and earn a return on investment ranging from 0.01% to 18.47% per year. Non-investing EU member states experience benefit leakages representing -5% to 55% of the overall welfare gains. In fact, seven of the 22 projects evaluated produce international benefit spillovers to EU members in excess of 20% of total welfare gains. Based on the authors’ findings, simple calculations suggest that non-EU non-investing countries also gain from benefit leakages, with estimates ranging from -1% to 28% of the overall welfare effect. In absolute terms, investment benefit leakages to non-investment EU members can reach as high as 342.5 million euros per year, while the maximum benefit leakages to non-EU members could exceed 270 million euros per year based on our calculations.

Aside from the aforementioned findings by van Exel et al. (2002), concrete evidence of the international benefit leakages from seaports investments is largely non-existent. Two noteworthy exceptions include Merk et al. (2013) and Santos et al. (2018), who investigate the regional economic impact of European seaports through a regional I-O methodology and allude to the potential seaport investment benefit leakages. A comprehensive evaluation of leakages, however, is missing from both of these studies.

Merk et al. (2013) quantify the interregional spillovers arising from four major seaports in north-west Europe including Rotterdam, Hamburg, Le Havre, and Antwerp. The authors take a regional I-O approach at the relevant port area and calculate the industry-specific backward linkages,
captured by the so-called Leontief multipliers. In terms of the aggregate effects, the calculations suggest that the ports of Le Havre and Hamburg have the largest impact relative to the ports of Rotterdam and Antwerp - a finding that is consistent across industries as well. Breaking these impacts down across regions, the authors find that the port of Rotterdam exercises significant influence over the port region of Antwerp and the cross-border Flanders’ region in general. The port of Antwerp has comparatively smaller supranational effects. Unfortunately, the authors do not provide international spillover estimates for the ports of Hamburg or Le Havre, although sizeable national spillovers are indicative of the potential cross-border leakages.

In a similar study, Santos et al. (2018) estimate the port multiplier effects for Portuguese seaports via the regional I-O methodology and find that the port multiplier of Leixões is significantly smaller than the estimated parameter for Lisbon. The authors explain their finding through the geographic location of the port Leixões in close proximity to the Spanish region of Galicia and allude to seaport benefit leakages across the Portuguese-Spanish border. Specific estimates of the leakages, however, are not provided, since the I-O methodology critically hinges on domestic input tables, which precludes the estimation of cross-border effects.

From this overview of the current state of knowledge on the cross-border distribution of transport investment benefits it has become clear that there are considerable gaps remaining in this literature. While recent advances in the realm of European road and railway investments have been made through the application of accessibility indicators and spatial computable general equilibrium models, much remains to be learned about investment benefit leakages in alternative geographic settings and seaport investments in particular. Moreover, researchers and policy makers would benefit from the application of a wider range of empirical techniques, such as spatial econometric models, able to quantify the domestic marginal benefits and differentiate these estimates from international marginal benefit leakages of an additional dollar invested into transport infrastructure.
4 Conclusion

In this study, we have reviewed the broadly defined literature on the economic impact of public capital expenditure and provided detailed evidence on the methodological approaches and empirical findings of the existing research investigating the effects of seaport and other transport infrastructure investments as well as the resulting international benefit leakages. The exact definition of investment benefits and methodological approaches vary widely across these studies, and our approach is to compartmentalize the literature distinguishing between, for example, the macroeconomic and labor market studies on the impacts of public capital expenditure as well as a detailed survey of the research examining the effects of transport infrastructure investments.

To develop the context for the more detailed survey of studies investigating the effects of transport infrastructure investments and seaports in particular, we first explore the main findings produced by multiple strands of the literature analyzing the macroeconomic, domestic spatial spillover, labor market, and industry-specific investment benefits of broadly defined infrastructure spending. Grounded in this context, we turn our attention to the seaport and transport infrastructure investment literatures and evidence the considerable degree of controversy regarding the exact magnitude of economic benefits and their geographic distribution - a finding that holds particularly true for the effects from seaport investments.

Through our review of the literature, we identify a variety of potential causes for these diverging benefit estimates, the most fundamental of which appear to be the definition of the exact impact area and identification of geographic benefit spillovers. While the latter has received a considerable degree of attention from a domestic perspective, we find that relatively little is known about the leakages of these investment benefits across national borders. Because of these leakages, an investment evaluation from a global welfare perspective may yield a positive investment decision that differs from the conclusions drawn from strictly domestic cost benefit analyses leading to underinvestment in transport infrastructure from a supranational point of view. Since transport infrastructure investments are moving towards a new paradigm of multilateral funding decisions, as evidenced by the European TEN-T program or the Chinese belt and road initiative engaging
various African, Asian and European countries, the supranational distribution of these investment benefits is becoming critical component of public policy.

In light of our survey, we recognize the important advances that have been made by the previous literature and evidence the following issues as important gaps remaining in this field of study. First, while we have a dense set of estimates identifying the static effects of infrastructure spending, the previous research has produced comparatively little evidence on the dynamics of the economic impact of transport infrastructure investments. Second, very few studies seriously consider the potentially decreasing returns to scale deriving from these public capital expenditures. A second highway network, duplicating the existing public capital stock, for example, would not be expected to have the same benefits as the first. To this date, we observe a significant lack of evidence concerning the rate at which economic benefits of transport infrastructure investments diminish. Lastly, the current state of knowledge on the cross-border distribution of transport investment benefits has been limited in geographic coverage and type of projects under investigation. While recent advances in the realm of European road and railway investments evidence significant international benefit spillovers, much remains to be learned about investment benefit leakages in a wider range of geographic settings, such as the United States, alternative transport infrastructures, including seaports, and the marginal benefit leakages of additional investments. From a policy perspective, each of these gaps represents a critical element in forecasting the anticipated economic impact of the proposed transport infrastructure investment and deserves more attention in future studies.
<table>
<thead>
<tr>
<th>Source</th>
<th>Methodology</th>
<th>Type of Infrastructure</th>
<th>Area of Study</th>
<th>Time Horizon</th>
<th>Elasticity Range</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mera (1973)</td>
<td>Production function</td>
<td>General public capital spending</td>
<td>Japanese Prefectures-Industry</td>
<td>1954-1963</td>
<td>0.12-0.50</td>
<td>Output elasticity with respect to (wrt) public capital is estimated at 22% in the primary, 50% in the secondary, and 12% to 18% in the tertiary sectors.</td>
</tr>
<tr>
<td>Aschauer (1989)</td>
<td>Production function</td>
<td>Multiple infrastructures</td>
<td>U.S. National</td>
<td>1949-1985</td>
<td>0.25-0.56</td>
<td>The preferred elasticity of income wrt public capital is 0.39 suggesting a higher return to public capital than private investments.</td>
</tr>
<tr>
<td>Aschauer (1990)</td>
<td>Output growth equation</td>
<td>Highway infrastructure</td>
<td>U.S. State</td>
<td>1960-85</td>
<td>0.22-0.38</td>
<td>One standard deviation increase in highway capital increases income growth by at least 0.13 percentage points.</td>
</tr>
<tr>
<td>Hulten &amp; Schwab (1991)</td>
<td>Production function</td>
<td>Multiple infrastructures</td>
<td>U.S. State</td>
<td>1970-1986</td>
<td>-0.344 to 0.054</td>
<td>Regressions evaluate the impact of public capital on multi-factor productivity and evidence insignificant effects.</td>
</tr>
<tr>
<td>Garcia-Mila and McGuire (1992)</td>
<td>Production function</td>
<td>Highway and education spending</td>
<td>U.S. State</td>
<td>1969-1983</td>
<td>0.044-0.165</td>
<td>Output elasticity wrt highway capital ranges between 0.044 and 0.045 and wrt education capital it ranges between 0.072 and 0.165.</td>
</tr>
<tr>
<td>Holtz-Eakin (1994)</td>
<td>Growth accounting</td>
<td>General public capital spending</td>
<td>U.S. State</td>
<td>1969-1986</td>
<td>-0.115 to 0.203</td>
<td>Results of insignificant public infrastructure effects hold at regionally aggregated level.</td>
</tr>
<tr>
<td>Evans and Karras (1994)</td>
<td>Production function</td>
<td>Multiple infrastructures</td>
<td>U.S. State</td>
<td>1970-1986</td>
<td>-0.110 to 0.102</td>
<td>Output elasticity wrt public educational services is estimated at 0.033 and statistically significant.</td>
</tr>
</tbody>
</table>
### Table 2: Spatial spillover effects

<table>
<thead>
<tr>
<th>Source</th>
<th>Methodology</th>
<th>Type of Infrastructure</th>
<th>Area of Study</th>
<th>Weight Matrix</th>
<th>Time Horizon</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forkenbrock and Foster (1990)</td>
<td>Cost-Benefit Analysis</td>
<td>Highway infrastructure</td>
<td>U.S. County</td>
<td>Contiguity</td>
<td>1988</td>
<td>Benefit/Cost ratio estimates for highway construction between Saint Louis, MO and Saint Paul, MN range from 0.8 to 2.8</td>
</tr>
<tr>
<td>Boarnet (1998)</td>
<td>Production function</td>
<td>Highway infrastructure</td>
<td>U.S. County</td>
<td>Similarity</td>
<td>1969-1988</td>
<td>Cumulative effects include direct effects (0.236-0.300) and indirect spillover effects (-0.806 to 0.125)</td>
</tr>
<tr>
<td>Chandra and Thompson (2000)</td>
<td>Earnings equation</td>
<td>Highway infrastructure</td>
<td>U.S. County-Industry</td>
<td>Contiguity</td>
<td>1969-1993</td>
<td>Earning effects from highways (%): Manufacturing 2-10; Retail -3 to -6; Farming -10 to -30</td>
</tr>
<tr>
<td>Cohen &amp; Morrison Paul (2004)</td>
<td>Cost function</td>
<td>Highway infrastructure</td>
<td>U.S. State</td>
<td>Economic Integration</td>
<td>1982-1996</td>
<td>Inter- and intrastate highway infrastructure reduces manufacturing costs (combined cost elasticity: -0.24). Output elasticity estimates range by infrastructure (ports: -0.017; roads: 0.088) and industry (const.: -0.025; agric.: 0.072).</td>
</tr>
<tr>
<td>Cantos et al. (2005)</td>
<td>Production function</td>
<td>Multiple transport infrastructures</td>
<td>Spanish Region-Industry</td>
<td>Economic Integration</td>
<td>1955-1996</td>
<td>Direct output elasticities wrt to local and transport infrastructure vary from 0.065 to 0.121 and -0.001 to 0.051, respectively.</td>
</tr>
<tr>
<td>Moreno and López-Bazo (2007)</td>
<td>Production function</td>
<td>Multiple infrastructures</td>
<td>Spanish Provinces</td>
<td>Multiple</td>
<td>1965-1997</td>
<td>Direct and indirect elasticity estimates wrt to highway capital range from 0.017 to 0.057 and -0.017 to -0.051, respectively.</td>
</tr>
<tr>
<td>Crescenzi and Rodríguez-Pose (2011)</td>
<td>Output growth equation</td>
<td>Highway infrastructure</td>
<td>EU Regions (NUTS 1 &amp; 2)</td>
<td>Nearest Neighbors</td>
<td>1990-2004</td>
<td></td>
</tr>
</tbody>
</table>

Continued on next page
Table 2 – *Continued from previous page*

<table>
<thead>
<tr>
<th>Source</th>
<th>Methodology</th>
<th>Type of Infrastructure</th>
<th>Area of Study</th>
<th>Weight Matrix</th>
<th>Time Horizon</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yu et al. (2013)</td>
<td>Production</td>
<td>Transport infrastructures</td>
<td>Chinese Regions</td>
<td>Contiguity</td>
<td>1978-2009</td>
<td>Integrating the Spatial Durbin Model into the common production function, the authors find diminishing direct and increasing regional spillover effects over the sample period.</td>
</tr>
<tr>
<td>Arbués et al. (2015)</td>
<td>Production</td>
<td>Multiple transport infrastructures</td>
<td>Spanish Provinces (NUTS 3)</td>
<td>Multiple</td>
<td>1986-2006</td>
<td>Total elasticity estimates wrt to transport infrastructure vary greatly (sea-ports: -0.043 to -0.012; motorways: 0.080 to 0.119) and are largely insignificant, except for motorway capital.</td>
</tr>
</tbody>
</table>
### Table 3: Spatial weight specifications

<table>
<thead>
<tr>
<th>Spatial Weight ($w_{ij}$)</th>
<th>Input Variables</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contiguity</strong> $\omega_{ij} = \begin{cases} 1 &amp; \text{if } i \text{ and } j \text{ are neighbors} \ 0 &amp; \text{otherwise} \end{cases}$</td>
<td>N/A</td>
<td>Forkenbrock &amp; Foster (1990), Eberts (1991), Dalenberg (1998), Chandra &amp; Thompson (2000), Moreno &amp; López-Bazo (2007), Ozbay et al. (2007), Jiwattanakulpaisarn et al. (2009), Gómez-Antonio &amp; Fingleton (2012), Yu et al. (2013), Shan et al. (2014), Song &amp; van Geenhuizen (2014), Fageda &amp; Gonzalez-Aregall (2017)</td>
</tr>
<tr>
<td><strong>$k^{th}$ Nearest Neighbor</strong> $\omega_{ij} = \begin{cases} 1/k &amp; \text{if } k &lt; K \ 0 &amp; \text{otherwise} \end{cases}$</td>
<td>k: order of contiguity between $i$ &amp; $j$ and K: arbitrary threshold assuming no spillover effects beyond the $K^{th}$ order of contiguity</td>
<td>Crescenzi &amp; Rodríguez-Pose (2011)</td>
</tr>
<tr>
<td><strong>Inverse Distance</strong> $\omega_{ij} = 1/d_{ij}$</td>
<td>$d_{ij}$: (Squared) Distance between centroids of regions $i$ and $j$</td>
<td>Moreno &amp; López-Bazo (2007), Jiwattanakulpaisarn et al. (2009), Bottasso et al. (2014)</td>
</tr>
<tr>
<td><strong>Proximity</strong> $\omega_{ij} = \begin{cases} 1 &amp; \text{if } d_{ij} &lt; 100 \text{ miles} \ 0 &amp; \text{otherwise} \end{cases}$</td>
<td>$d_{ij}$: Distance between centroids of regions $i$ and $j$.</td>
<td>Arbués et al. (2015), Fageda &amp; Gonzalez-Aregall (2017)</td>
</tr>
<tr>
<td><strong>Market Potential</strong> $\omega_{ij} = x_j/d_{ij}^2$</td>
<td>$x_j$: Value added in region $j$ $d_{ij}^2$: Squared distance between the centroids of regions $i$ and $j$.</td>
<td>Moreno &amp; López-Bazo (2007)</td>
</tr>
<tr>
<td><strong>Region Similarity</strong> $\omega_{ij} = \frac{1}{\sum_j 1/</td>
<td>x_i - x_j</td>
<td>}$</td>
</tr>
</tbody>
</table>

Notes: For the $k^{th}$ nearest neighbor spatial weights, first order contiguity is defined through sharing a common border between region $i$ and $j$. Second order contiguity is based on sharing a common border between region $i$’s first-order neighbors and region $j$. Higher orders of contiguity are defined accordingly.
Table 4: Labor market effects

<table>
<thead>
<tr>
<th>Source</th>
<th>Methodology</th>
<th>Type of Infrastructure</th>
<th>Area of Study</th>
<th>Time Horizon</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carlino and Mills (1987)</td>
<td>Steinnes and Fisher model</td>
<td>Highway infrastructure</td>
<td>U.S. County</td>
<td>1970-1982</td>
<td>Elasticity estimates of employment and population wrt highway infrastructure equal 0.061 and 0.028, respectively.</td>
</tr>
<tr>
<td>Deno (1988)</td>
<td>Translog profit function</td>
<td>Multiple infrastructures</td>
<td>U.S. MSA</td>
<td>1970-1978</td>
<td>Elasticity estimates of manufacturing output, employment, and private capital wrt total public capital range from 0.613 to 0.815 and vary greatly across individual types of infrastructure (Water: 0.019; Highway: 0.571).</td>
</tr>
<tr>
<td>Munnell and Cook (1990)</td>
<td>Production function</td>
<td>General public capital spending</td>
<td>U.S. State</td>
<td>1970-1986</td>
<td>Elasticity estimates of output vary across infrastructure (water and sewer: 0.12; highway: 0.06) and exceed those of employment (0.0001 to 0.0002).</td>
</tr>
<tr>
<td>Duffy-Deno and Dalenberg (1993)</td>
<td>Labor supply and demand equations</td>
<td>General public capital spending</td>
<td>U.S. MSA</td>
<td>1970-1980</td>
<td>Elasticity estimates of employment wrt public capital equals 0.067, while the estimated wage elasticity wrt to public capital is insignificant. The elasticity of labor demand wrt infrastructure exhibits substitutability (-0.0986 to -1.6196) and wrt publicly financed R&amp;D it exhibits complementarity (0.651 to 0.444).</td>
</tr>
</tbody>
</table>

Continued on next page
<table>
<thead>
<tr>
<th>Source</th>
<th>Methodology</th>
<th>Type of Infrastructure</th>
<th>Area of Study</th>
<th>Time Horizon</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dalenberg and Partridge (1995)</td>
<td>Disequilibrium framework</td>
<td>Highway &amp; non-highway public capital</td>
<td>U.S. MSA - Industry</td>
<td>1966-1981</td>
<td>The estimates of the effects of highways (-0.018 to -0.116) and more broadly defined infrastructure (-0.003 to -0.007) on labor suggest the substitutability between these factors of production.</td>
</tr>
<tr>
<td>Haughwout (1996)</td>
<td>Urban equilibrium model</td>
<td>General public capital spending</td>
<td>U.S. MSA</td>
<td>1974-1985</td>
<td>Elasticity estimates of employment, land values, and wages wrt public infrastructure equal 0.099, 0.035, and -0.014. The wage effect, however, is indistinguishable from zero.</td>
</tr>
<tr>
<td>Clark and Murphy (1996)</td>
<td>Steinnes and Fisher model</td>
<td>Multiple infrastructures</td>
<td>U.S. County - Industry</td>
<td>1981-1989</td>
<td>Total employment growth responds positively to defense and police spending as well as property taxes. At the industry level, however, these responses vary drastically.</td>
</tr>
<tr>
<td>Wu and Gopinath (2008)</td>
<td>Urban equilibrium model</td>
<td>Multiple infrastructures</td>
<td>U.S. County</td>
<td>2000</td>
<td>The structural estimates suggest a simultaneous determination and positive effect of road density on labor demand, as well as the supply and demand of land development. The development of highways in rural counties increases the skill premia in skill abundant locations and reduces the wages in less educated counties.</td>
</tr>
<tr>
<td>Source</td>
<td>Methodology</td>
<td>Type of Infrastructure</td>
<td>Area of Study</td>
<td>Time Horizon</td>
<td>Summary</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>----------------------------------</td>
<td>------------------------</td>
<td>------------------</td>
<td>--------------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Jiwattanakulpaisarn et al. (2009)</td>
<td>Employment growth VAR model</td>
<td>Highway infrastructure</td>
<td>U.S. State</td>
<td>1984-1997</td>
<td>Interstate highway infrastructure is estimated to have a positive agglomeration effect that drives lagged local employment growth.</td>
</tr>
<tr>
<td>Gómez-Antonio and Fingleton (2012)</td>
<td>NEG wage equation</td>
<td>General public capital spending</td>
<td>Spain - Provinces</td>
<td>1985-2005</td>
<td>Direct elasticity estimates of wages wrt to public capital range from 0.051 to 0.213, whereas the indirect estimates range from -0.008 to -0.373 and point to negative spatial spillovers and redistribution of economic activity.</td>
</tr>
<tr>
<td>Möller and Zierer (2018)</td>
<td>Employment growth equation</td>
<td>Highway infrastructure</td>
<td>Germany</td>
<td>1994-2008</td>
<td>The key finding suggests that a one standard deviation increase in highway growth raises employment and wage growth by 2.7</td>
</tr>
<tr>
<td>Heuermann and Schmieder (2018)</td>
<td>Gravity model</td>
<td>Rail infrastructure</td>
<td>Germany - NUTS 3</td>
<td>1994-2010</td>
<td>The elasticity estimate of commuter supply wrt commuting time equals 0.25 and is driven by urban residents seeking employment in more rural areas.</td>
</tr>
</tbody>
</table>
Table 5: Economic impact of seaports

<table>
<thead>
<tr>
<th>Source</th>
<th>Methodology</th>
<th>Type of Infrastructure</th>
<th>Area of Study</th>
<th>Spatial Spillovers</th>
<th>Time Horizon</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ferrari et al. (2010)</td>
<td>Employment equation</td>
<td>Port throughput</td>
<td>Italy - Provinces</td>
<td>N</td>
<td>2000-2006</td>
<td>Elasticity estimates of total and service sector employment wrt to maritime traffic range from 0.015 to 0.022.</td>
</tr>
<tr>
<td>Bottasso et al. (2013)</td>
<td>Employment equation</td>
<td>Port throughput</td>
<td>EU Regions - Industry</td>
<td>N</td>
<td>2000-2006</td>
<td>Elasticity estimates of total, service, and industry employment wrt to maritime traffic range from 0.00017 to 0.001 depending on seaport organizational structure.</td>
</tr>
<tr>
<td>Bottasso et al. (2014)</td>
<td>Spatial Output Model</td>
<td>Port throughput</td>
<td>EU Regions</td>
<td>Y - Distance</td>
<td>1998-2009</td>
<td>Elasticity estimates of output wrt maritime traffic range from 0.069 to 0.021, while spillover effects exceed direct impacts.</td>
</tr>
<tr>
<td>Shan et al. (2014)</td>
<td>Output growth equation</td>
<td>Port throughput</td>
<td>China - Port city</td>
<td>Y - Contiguity</td>
<td>2003-2010</td>
<td>A 1</td>
</tr>
<tr>
<td>Song and van Geenhuizen (2014)</td>
<td>Production function</td>
<td>Transport infrastructures</td>
<td>China - Port regions</td>
<td>Y - Contiguity</td>
<td>1999-2010</td>
<td>Elasticity estimates of output wrt to local seaport infrastructure range from 0.093 in the Center to 1.428 in the Yangtze River Delta region and create largely positive spillover effects.</td>
</tr>
</tbody>
</table>

*Continued on next page*
Table 5 – *Continued from previous page*

<table>
<thead>
<tr>
<th>Source</th>
<th>Methodology</th>
<th>Type of Infrastructure</th>
<th>Area of Study</th>
<th>Weight Matrix</th>
<th>Time Horizon</th>
<th>Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breidenbach and Mitze (2016)</td>
<td>Production function</td>
<td>Port infrastructure</td>
<td>Germany - NUTS 3</td>
<td>N</td>
<td>1991-2008</td>
<td>The OLS estimates provide evidence of a positive correlation between port location and per capita income, whereas the IV estimates do not produce any evidence of a causal port effect on output. The estimates suggest that Korean cargo ports only stimulate regional growth if throughput reaches a critical mass of around 115 million tons per year. For these larger ports, a 1% increase in port throughput results in a 0.242 to 0.755% increase in employment, which is driven by significant direct effects (0.292-0.361). Total elasticity estimates of manufacturing employment with respect to port throughput range from 0.242 to 0.755 and are driven by significant direct effects (0.292-0.361). Primary elasticity estimates of employment, land values, and wages with respect to port throughput equal 0.033, 0.049, and -0.011, respectively. Seaport throughput causes interindustry reallocation towards transport sectors and creates spatial spillovers, which vary by geographic and economic characteristics.</td>
</tr>
<tr>
<td>Park and Seo (2016)</td>
<td>Augmented Solow growth model</td>
<td>Port throughput</td>
<td>Korea - Regions</td>
<td>N</td>
<td>2000-2013</td>
<td></td>
</tr>
</tbody>
</table>
Acknowledgments

The authors gratefully acknowledge discussions with Kenneth Casavant, Kevin Knight and Ian Mathis. Of course, any errors or omissions are the authors’ alone. Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Notes

4For related empirical evidence on determinants of FDI, see, for example, Woodward (1992); Florida et al. (1994); Coughlin and Segev (2000) or Kim et al. (2018)
5For many parts of the world, seaports are viewed as primarily public goods and seaport finance continues to be largely shouldered by public entities at the local, regional, or national level (Baird 2004). The application of seaport user fees is rare and clearly contrasts the financing of international airports, which heavily depend on airport improvement fees levied on passengers and cargo (Zhang, 2012).
9A detailed discussion of these four approaches goes beyond the scope of this literature review and would merely duplicate the summaries offered by Castro and Milán (1998); Benacchio and Musso (2001); García and López (2004); Francou et al. (2007); Acciaro (2008), and Dooms et al. (2015).

References


