Complementing clusters: a competitiveness rationale for infrastructure investments

Amir Sasson
BI Norwegian Business School

Torger Reve
BI Norwegian Business School

Competitiveness Review, 25(2015)3: 242-257

DOI: 10.1108/CR-12-2014-0040

Publisher's version available at http://dx.doi.org/10.1108/CR-12-2014-0040

Complementing Clusters:
A Competitiveness Rationale for Infrastructure Investments

Ever since the seminal publication of 'The Competitive Advantage of Nations' (Porter, 1990) clusters have directed public policies and industrial incentives across the globe (e.g., European Commission, 2008). The ever growing body of research has examined important cluster effects such as entrepreneurship (Delgado, Porter, and Stern, 2010a; Sorenson and Audia, 2000), job creation and economic performance (Delgado, Porter, and Stern, 2010b), location choices (Zaheer, Lamin, and Subramani, 2009), innovation (Bell, 2005), and knowledge creation and transfer (Arkian, 2009; Giuliani, 2007; Jaffe, Trajtenberg, and Henderson, 1993; Reve and Sasson, 2012; Tellman *et al.*, 2004).

We contribute to the extant literature by examining the role of clusters in affecting the return on investment of large infrastructure projects. Our study complements current cluster research which provides an impressive body of literature and empirical findings on: a) cluster economic outputs (Delgado *et al.*, 2010a; Delgado *et al.*, 2010b; Porter, 1998; Wilson, Lindbergh, and Graff, 2014) as those mentioned in the previous paragraph and b) cluster processes and policies (Niu *et al.*, 2012; Sölvell, Lindqvist, and Ketels, 2003; Zettinig and Vincze, 2012).

Currently, decision makers base the evaluation of large infrastructure projects on the assessment of the degree to which infrastructure investments a) provide more efficient transport solutions and b) contribute to urbanization through increases in population size (Calem and Carlino, 1991; Jacobs, 1969; Venables, 2007). The former is a cost saving rationale through reduced logistics costs and the latter is an indirect value addition through urbanization. We complement these two rationales by advancing a value creation argument based on a cluster complementarity foundation for the evaluation of large infrastructure projects.

We based our conceptual development on the idea of "economic islands". We define two areas as separated to the degree to which current transport time de facto prevents the labor force in one area from engaging in economic activities in the other area. The existence of economic islands prevents or seriously impede the operation of the primary cluster mechanisms of knowledge spillovers (Jaffe *et al.*, 1993), local supplier specialization (Marshall, 1920), labor market pooling (Marshall, 1920), intense local competition and demanding local customers (Porter, 1990). Large infrastructure investments have the potential to unite economic islands into a cohesive economic area, unleashing these pivotal cluster mechanisms, which are responsible for cluster benefits. The cohesiveness of the economic area is dependent on public policy (Porter, 2008) and cluster specific policies (Sölvell *et al.*, 2003) and their implementation.

The unification of currently two separated economic islands is a form of instantaneous cluster upgrade. From a cluster upgrade perspective, we thus pose the following question: To what extent do the economic islands complement one another? We argue that the potential for value creation is directly dependent on the degree of complementarity between the clusters in the respective economic islands. Imagine a scale that varies from zero to one and indicates the degree of cluster complementary between the currently two separated economic islands. At the lower end of the scale, two islands have historically specialized in two different, unrelated and non-complementing economic clusters. Under these theoretical condition, we expect value effects to be related to transportation cost reductions and increased population size and urbanization (Jacobs, 1969). On the other end of the scale, the two islands have historically specialized either in the same narrowly defined economic activity or in related activities along the same value chain. The underlying rationale for value now includes transportation costs, increased size and urbanization and cluster complementarity. The latter represents the major value creation mechanism. In fact, creating larger and stronger clusters through larger and more productive labor markets often

represents the major argument for new infrastructure investments. This cluster complementary effect comes in addition to regular urbanization effects, where cities typically have higher productivity and higher value creation per employees than less urbanized regions (Glaeser, 2011).

Hence, cluster complementarity analysis aims at identifying the degree to which unification has the potential to create value through the strengthening of the underlying mechanisms that are responsible for value creation in clusters. Cluster complementarity relates to value creation because the degree of cluster complementarity directly influences the intensity by which cluster mechanisms operate. Higher cluster complementarity increases the likelihood of knowledge spillovers, supplier specialization, labor market pooling, and existence of demanding customer and obviously intensifies competition. Such industrial clusters tend to have higher innovation capacity and higher entrepreneurship rates, as well as attracting more firms and talents from the outside. These factors combined lead to more job creation and higher productivity in existing firms.

We commence with the identification of the degree to which current economic islands are actually isolated. Thereafter, we examine the degree to which clusters complement one another. We evaluate clusters complementarity in terms of market structure and human capital. We utilize the insights gained through cluster complementarity analysis in order to estimate the value creation potential of economic island unification. We find that when cluster complementarity is high, the potential for value creation in the unified economic area surpasses the entire costs of the infrastructure investment tipping the investment decision in favor of such an investment. We find the opposite when cluster complementarity is low.

We provide a comparative and quantitative case study of multiple investments that connect economic islands along a highway the stretches over 1100 kilometers (683 miles) from Kristiansand in Southern Norway to Trondheim in Central Norway, referred to as the E39 project. It currently takes more than 20 hours (on average 55 km per hour) and the use of no less than seven

ferries to pass through the road today. Road toll and ferry levies and the cost of driving time amount to 20962 NOK ($ 3261) for a truck, which drives through the entire road. The estimates costs of replacing the ferries by underwater tunnels and fjord crossing bridges, as well as upgrading the road into a modern standard highway, amount to more than 150 billion NOK ($ 21 billion). This will reduce transport time by 8-9 hours and halve the costs of driving through this rather exotic road trip. As we will show in the empirical analysis provided below, the reduced transportation time and the reduced logistics costs are not the primary economic gain of this large infrastructure investment along the West Coast of Norway. The integration of regional labor markets and exiting clusters produces the main economic effects.

Cluster complementarity

Unified geographical regions, which overcame a geographical barrier, have the potential to unleash cluster mechanisms that are currently none or poorly functioning. The degree to which cluster mechanisms can be unleashed is dependent on first, the magnitude of the geographical barrier and second the degree of cluster complementarity. The former establishes the extent to which the barrier is actually a hinder for the operation of cluster mechanisms. A high geographical barrier isolated business communities and labor markets and prevents or substantially hinders supplier specialization, employee mobility and knowledge flows. The later, cluster complementarity, establishes the degree to which the business communities and labor markets on each side of the geographical barrier complement one another. Complementarity is a multi-facet construct. In our conceptualization, we focus on 1) Market structure complementarity, the similarity of the industrial portfolios and the addition to critical mass for each industry due to unification and 2) Talent complementarity, the similarity of the portfolio of the human capital stock.

INSERT FIGURE 1 HERE

In specific, we examine three major fjord crossings depicted in Figure 1. The first crossing connects the "economic islands" of Stavanger and Haugesund over Boknafjorden, with the distance between the two main cities being about 81 km. An operational definition of the geographical scope of each of the economic is the culturally specific acceptable time for commuting for working purposes. In our context, that is, one hour drive. The estimated costs of building the crossing only is 12 billion NOK. The discounted transport benefit is estimated to be, on average, 1.2 billion NOK per year (Minken, 2013: using 40 years and a discount rate of 4.5%). The expected added productivity from increased labor market is estimated to be 649 million NOK per year (Norman and Norman, 2012). We share with Norman and Norman (2012) the focus on productivity gains but we differ on the cause for such gains. Norman and Norman (2012) estimate productivity gains to employees originating through an increase in the size of the labor market. They ignore cluster complementarity. Only labor market size matters. We estimate value creation gains to all economic actors originating through the degree of cluster complementarity.

Stavanger region, which includes one of the biggest and most dynamic municipalities in Norway (Stavanger), had working force of 121,109 employees in 2011. Labor market in Haugesund is one fourth in size with 31,204 employees. In the years 2001-2011 the number of employees in the Haugesund region increased by 28 percent, when the corresponding number in Stavanger is 36.8 percent. The major industry by share of employees engaged in Stavanger is Offshore Oil and Gas (16.6%), while in Haugesund it is Health (24.3%) and Maritime. Currently for every one NOK of value creation produced in the Haugesund region, the Stavanger region produces 16 NOK, indicating varying productivity levels between regions. Value creation growth

further supports differing productivities are likely to increase. The growth in value creation in the Stavanger region in 2001-2011 was 102% while the corresponding percent for Haugesund being only 85%.

The next two regions are Ålesund and Molde over Moldefjorden with about 70 km (43 miles) between two locations. 24,577 employees worked in the Ålesund region, while the Molde region is smaller, with 14,581 employees. The estimated costs of building the crossing only is 8 billion NOK. The discounted transport benefit is estimated to be, on average, 0.25 billion per year (Minken, 2013). The expected added productivity from increased labor market is estimated to be 303 million NOK per year (Norman *et al.*, 2012). The two regions have similar distribution of employees per industry, with Retail being the biggest one. The Ålesund region has value creation per employee, which is 160,000 NOK higher than in the Molde region providing evidence for ex-ante productivity differences. The Ålesund region contains a strong and dynamic cluster in the maritime offshore industry, while Molde is more an administrative center with a major hospital, a university college and public services.

Løvik and Oppedal are two small regions north of Bergen, separated by Sognefjorden, famous for its spectacular scenic nature. Løvik employs only 9,079 people, while the work force in Oppedal totals 5,428 employees. The estimated costs of building the crossing only is 15 billion NOK. The discounted transport benefit was not estimated (Minken, 2013) but it is argued to be lower than 190 million NOK. The expected added productivity from increased labor market is estimated to be 105 million NOK per year (Norman *et al.*, 2012).

Løvik also accounts for more people with university education (26%), with only 15% in Oppedal. The largest industries in terms of the number of employees are Retail in Løvik and Offshore Oil and Gas in Oppedal. For every NOK of value creation produced in the Oppedal region,

the Løvik region produces 1.5 NOK. The value creation growth in the Oppedal region in 2001-2011 was 44% while the corresponding percent for Løvik was 36%.

In order to evaluate the degree of ex-ante fusion, their market structure and human capital complementarity and estimate the potential for value creation following unification we utilize a unique dataset. Statistics Norway provided us with data on the characteristics of every employee in Norway over the period 2000-2012. The data includes general demographic information including human capital, place of residence and place of employment. In addition, to the population of employees we also received data covering the entire balance sheets and profit and loss statements for all firms operating in Norway during those years. These rich data sets allow us to directly describe the economic islands studies here and estimate rather accurately the potential for value creation.

The degree of ex-ante fusion

Studies of the mobility of patent holders indicate that employee mobility is central for knowledge transfer across boundaries (Almeida and Kogut, 1999; Jaffe *et al.*, 1993). The absence of mobility hinders learning in non-patenting organizations. In a similar vein, the absence or presence of employee mobility across a fjord affects knowledge transfer as well as supplier specialization, the degree of competition and labor market pooling. To what extent are two areas on opposite side of a fjord isolated? High degree of employee mobility indicates that cluster mechanisms are already at work while low employee mobility across the fjord hinders the operation of cluster mechanisms.

In order to examine the degree of isolation between the communities on each side of the respective fjords, we examine the percent of employee who lived in one region but worked in the other region, that is, on the other side of the fjord. For comparison, we first include the percent of

commuters out of the number of people in employment in regions without a geographical barrier. In the local authority of Bergen, the second largest city in Norway and the largest along the E39 road, 21% of all employees live in neighboring local authorities. The respective number of Oslo, the capital of Norway, is 42%. The corresponding percent in Stavanger is 42%. In the Stavanger - Haugesund crossing only 1.5% of the working population commuted across the fjord. The centrality of the oil and gas cluster in Stavanger and substantial shortage of qualified labor makes remuneration specifically attractive in the Stavanger region increasing the willingness to commute. 80% of individuals, who cross the fjord, do so from Haugesund to Stavanger.

In comparison, the degree of isolation between the two sides of the fjord is much higher in the case of the Ålesund - Molde crossing. Currently, only 0.9% of the work force travels across the fjord for employment purposes. The degree of isolation is even higher for the Løvik - Oppedal crossing over Sognefjorden. Currently, only 0.2% of the working population travels across the fjord for employment purposes. The analysis establishes the degree of integration between each of the above-mentioned economic islands. While cluster mechanisms can be unleashed when the geographical barrier is eliminated or reduced, the degree to which cluster mechanisms can upgrade the economies of currently remotely connected areas is dependent on the degree of complementarity between these areas.

Previous research used the co-location of two or more industries in the same statistical economic area as a proxy for cluster formation (Delgado *et al.*, 2010a; Delgado *et al.*, 2010b). The existence of the same industries in a neighboring statistical economic area indicates the geographical spread of the cluster. We supplement this methodology by posing the following question: To what extent do the clusters existing on each side of the geographical barrier complement one another? Complementarity is a multi-facet construct. In our specific conceptualization of cluster complementarity, we focus on 1) Industrial complementarity, the

similarity of the industrial portfolios and the addition to critical mass for each industry due to unification and 2) Talent complementarity, the similarity of the portfolio of the human capital stock.

Industrial complementarity

To quantify the similarity of market structures in two regions we gather employment data for each individual working in all the above-mentioned regions. We aggregated individual employment data by matching every individual employee with the industry affiliation of their employer. We compared employment data in each industry for one side of each geographical barrier in 2011 with the same data for the other side of the geographical barrier. We first examine the correlation between the percent of employment in each industry in each area. The most similar regions are Ålesund and Molde. The correlation between the industrial portfolios of these regions is 0.92. This means that industrial portfolios across the regions share 84% of the variance. Similarly, the correlation between the industrial portfolios of Stavanger and Haugesund is 0.83. The industrial portfolio across the regions share 69% of variance. In comparisons, the industrial portfolio between the two regions along the Sognefjorden correlates at the 0.53 level, which means that the shared variance is merely 28%.

When analyzing complementarity in more detail, we divide industries into two types, local and traded industries. Local industries serve the local market, and their volume is roughly proportional to the population in the region. Examples of local industries can be Construction, Retail, Transportation, Health Services, etc. Traded industries are selling their products and services across other regions and countries as well, and can be region-specific, dependent on location, available resources, and historical specialization. Those industries can include Mining,

Metals, Renewables, Knowledge-based services, Maritime, Oil and Gas, and Fishery and Aquaculture. The three latter ones are the three major export industries of Norway.

Due to the high correlation between Molde and Ålesund, we should not expect much difference in the distribution of employees by local industries. In both regions, Retail and Construction employ a significant share of employees (in Molde: 21.2 percent in Retail and 14 percent in Construction; in Ålesund: 27.6 percent in Retail and 12.1 percent in Construction). Major traded industries include Maritime, which employs 8.8 percent of labor force in Ålesund and 6.4 percent in Molde, while Knowledge-based Services, which specialize in supporting the Maritime industry, employ 5 percent of the labor force in each region.

Major local industries in Stavanger and Haugesund are Health, Retail and Construction, with Haugesund employing higher portion of employees in each of them than in Stavanger. We explain such disproportion with Stavanger, which is the oil capital of Norway, employing a significant share of working force (16.6 percent) in Offshore Oil and Gas, which is a major traded industry. The number of employees engaged in this sector increased by 43% between 2001 and 2009, while total employment in the region increased by 35 percent. Hence, the Offshore Oil and Gas industry has attracted employees from other industries. The metal industry is more developed in the Stavanger region employing 16.6 percent in comparison to 0.9 percent in Haugesund. Maritime, another important traded industry employs equal share of employees in both regions, which accounts for 7 percent. Knowledge-based services are strongly developed in two regions (10 percent in the Stavanger region and 7.5 percent in Haugesund region) and support Maritime and Offshore Oil and Gas, and other traded industries.

We established above that the industrial portfolios of Løvik and Oppedal differ substantially. Here local industries, like Retail, Construction, and Health, employ the largest share of employees in both regions. The Oppedal region characterizes by substantial oil and gas activities,

where 17.8% of labor force works, and Mining activities (3.2 percent). In the Løvik region, Maritime is the most significant traded industry (4.6 percent), with only 2.5 percent in Oppedal. Knowledge-based services in both regions support their traded industries and employ 6.9% and 3.6% of total employees in Oppedal and Løvik respectively.

Critical mass of firms affects the visibility and attractiveness of clusters, the likelihood of the existence of direct competition and the potential for intra-industry mobility and supplier specialization. A unification of areas currently separated by a geographical area, has the potential to increase the number of firms in each cluster in the united area. Even though Molde and Ålesund have similar distribution of employees across industries, some of them will benefit more due to changes in the number of firms. In the unified area, the number of companies in Mining and Quarrying can increase from four companies to 15. The Food industry can increase from 13 firms to 60. Major traded industries in Molde (Maritime and Knowledge-based Services) will result in significant increase in number of firms (213% in both).

Stavanger region, being four times larger region than the Haugesund region in terms of employment, will benefit substantially from increased number of firms in the Maritime and Seafood Industries. Relative to the number of firms before unification, the total number of firms will increase by 165% and 300% respectively. This will significantly influence the Maritime industry in Stavanger, which employs the 7% of labor force. Knowledge-based Services, supporting Maritime as traded industry, can change its critical mass by 504%.

The unification of the Oppedal and Løvik regions will have only marginal effect on critical mass. The important offshore oil and gas industry in Oppedal will not increase in size by the unification. Effects that are more visible will occur in the context of the Maritime and Knowledge-based Services number where the number of firms, seen from the Oppedal region perspective will increase by 111% and 200% respectively.

Talent complementarity

We continue with the examination of talent complementarity between the regions. Stavanger and Haugesund regions differ in terms of human capital composition but the gap is not as radical as in Løvik and Oppedal. While the percent of the workforce with secondary education or below is 23% and 24% in Stavanger and Haugesund respectively, the differences are evident in terms of the distribution of human capital at higher levels of education (See Table 1). While the Haugesund region is populated with employees with high school education, which constitutes over half of the human capital, only 19% hold a Bachelor degree, 4% hold a Master degree and an insignificant number hold a doctorate (0.1%). In comparison, 21% of the employees in the Stavanger region hold a Bachelor degree, 9% hold a Master degree and 0.6% hold a doctoral degree.

INSERT TABLE 1 HERE

We explain the reason for such distribution by the presence of universities in Stavanger, which supports the main traded industries there and the engineering intensive Oil and Gas sector, University of Stavanger offers degrees in petroleum technology, offshore technology, and other related specializations, preparing engineers who are in a high demand in the region. BI Stavanger offers a degree in business administration, as professional services employ a significant amount of students in the region. Stord/Haugesund University College offers a degree in marine studies, safety management, etc., but the size of the university college is much smaller comparing to University of Stavanger. Uniting the two “islands” would increase competition between the two schools, thus increasing their quality and widening the range of available specializations.

Ålesund and Molde regions have a complementary structure of human capital in terms of the level of education. 21% in Ålesund have a university degree, with the corresponding number of 19% in Molde. The region with slightly more human capital is also showing higher growth in the corresponding share. In Ålesund, secondary school and high school education graduates constitute 79 percent of the workforce and 81 percent in Molde. The share of people with business administration education in Ålesund is higher than in Molde, with both regions having the same increasing tendency. There are two university colleges in the area: Ålesund University College and Molde University College, with the college in Ålesund being more oriented towards engineering and maritime and College in Molde towards business administration, logistics and health. Uniting two regions and simplifying movement between them can bring people with new competencies and specializations, supporting existing traded industries. Thus, Ålesund and Molde show high similarity in shares of people with university degree, and trends in human capital changes, from which we can expect high complementarity and value creation.

The population of employees in the Løvik region has higher formal human capital than the one in Oppedal. University graduates amount to 26% of the working population in Løvik in comparison to 15% in Oppedal (While 22% of employees in the Løvik region hold a Bachelor degree, only 12% do so in the Oppedal region). Thus, the Oppedal region has a larger percent of employees who have graduated from either high school or secondary school, which makes Løvik region more attractive for employers who look for qualified employees. The share of the workforce with business education out of total employment in Løvik is twice as large (3 %) relative to Oppedal.

Value creation

As mentioned above, the unification of two economic islands contributes to the integration of the labor market and the elimination of productivity differences. In this section, we will present a framework that will examine the potential for value creation arising from the unification of the economic islands under examination in the present study.

Firstly, we start with a scenario in which no integration exists. The industries operating in unconnected economic regions will not benefit from cluster complementarities. Therefore, productivity differences will subsist throughout time. If a connection were to be established, it would alter the pre-established path. More specifically, it would allow a cluster to access a greater labor market pool and enjoy potential knowledge spillovers, experience greater supplier specialization and potentially expose firms to direct competitors.

Figure 2 illustrates the expected productivity evolution in a certain industry, along a 10-year period[1]. We will now explain the model in more detail. On the left side of Figure 2, we present the scenario in which municipalities remain separated (from now on, "Current Values"). The productivity, measured in the vertical axis, represents the amount of net income and salaries contributed by a single employee in an industry ("Value creation per employee" or "VCE"), i.e. we obtain the variable by dividing the total value generated per industry and region by the total number of employees in the industry and region. The industry exemplified has a higher productivity in one economic region ("Municipality A") than in the other region ("Municipality B"), creating a gap not altered by time (measured in the horizontal axis). An underlying assumption is a similar growth rate affecting the same industry in both regions.

[1] Although simulations can consider different periods, we found that this length allows the necessary absorption of knowledge, while accounting for possible improvements in the connection. Longer periods can be less realistic in terms of isolating from other effects, namely public or private policies that encourage mobility and industry development.

INSERT FIGURE 2 HERE

We collected 2009 value creation per employee data from every industry in the economic islands under consideration, setting that level as the starting value of productivity (Year 0). We took a conservative approach and excluded industries with less than 10 firms and firms with less than 20 employees. We also assumed that the growth of the economic islands would be constrained to GDP annual growth rate, thus excluding additional growth drivers. Since we used 2009 value as basis for our estimates, we used historical GDP growth rate between 2009 and 2013 for the first years of forecasts, taken from Statistics Norway, and its estimates for the rest of the period. We could have used historical compounded growth rates of the VCE of each industry, but we did not possess the necessary information to account for recent extraordinary events, their impact and duration, that would have made the estimates unviable.

The right side of the Figure 2 presents the scenario with the unification of the economic islands ("Estimated Values") for one industry. Here, there are two key assumptions considered. On the one hand, the industry with higher productivity maintains the same growth trend as observed in the Current Values scenario. We expect to find benefits in both regions. The integration of the markets would allow to share know-how throughout space and time and to maximize an industry´s potential. Despite that, a more conservative perspective suggests that mobility will not be completely spread in the entire population, limiting the levels of potential value. In addition, the region that reveals higher productivity before the connection may have already attracted the most talented collaborators, creating a virtuous cycle of development. On the other hand, it is assumed that the industry with lower productivity would experience a steeper growth and eventually reach the same value creation per employee as the more productive area (evolution portrayed with dashed

line). We calculate this potential achievement, of matching productivity levels, via a linear growth, throughout a 10-year period.

Our assumptions are conservative ones. Clusters, all else equal, should be the growth engines and hence grow faster than the rest of the economy. We however assume both the growth of the more productive industry will merely follow the national GDP growth and that no new firms, employees or projects would interfere, concentrating change merely in knowledge flows. Finally, we also excluded the financial industry, due to its abnormal historical results that could positively bias our estimates.

Having set the mechanism for a single industry at the employee level and in possession of the forecasted values in both Current and Estimated Values, we amplified the effect for the entire industry. Hence, we multiplied forecasted value creation per employee in both scenarios by the number of existing employees. Figure 3 exemplifies the results for an industry.

INSERT FIGURE 3 HERE

As a remainder, the black full line represents the productivity evolution of a hypothetical industry in the economic region that showed in Year 0 the highest value creation per industry. The full and dashed grey lines represent the Current and Estimated Values of the less productive industry-region combination, respectively. We can now observe the magnitude of the value creation generated: it is the visible grey area. It represents all the additional value creation in addition to the expected value creation growth from continued economic isolation. Value creation is thus generated by higher growth rate of the industry-region combination, which is less productive.

In order to obtain the value creation of the integrated markets, we simply replicated the process for all industries, aggregating the additional created values. The results are nevertheless affected by time, so we discounted the yearly added value at different growth rates. For simplification purposes, we show only the results when considering a 3% discount rate (a value close to interest rates of government bonds for a 10-year period). The final step of our analysis was to calculate what would be an average annual added value, by simply dividing the total added value in a crossing by 10.

The annual value permits a comparison with the results from a simpler method that we used for validity purposes. This simpler method consists on ignoring time effects and assuming that the full potential of an industry-region combination with lower productivity increase is reached overnight, as if all potential mobility and value creation were automatically achieved. Although unrealistic, it eliminates the natural growth imposed as base scenario.

INSERT TABLE 2 HERE

On the left column of Table 2, we present each crossings, and we can find an annual added value per employee, according with a convergence of markets throughout 10 years and with a 3% discount rate and with the immediate process, the simpler calculation. These estimates are very useful for our purposes. While they are sensitive to the number of employees in the regions, the costs of infrastructure development are not. We therefore included in the third column, added value per employee and in the fourth column, the percent of value creation out of the total expected costs of building the geographical bridge between the isolated economic islands.

Discussion

To our knowledge, this is the first time that cluster theory and empirical measures of cluster complementarity are applied to large-scale infrastructure projects. The Norwegian E39 project is a major infrastructure investment, totaling more than $ 20 billion in investments. Using regular transportation economics analyses, the documentation of logistics savings in this magnitude would be almost impossible. We argue that the savings in travel and logistics costs only represent a minor element in the social and economic benefits of new infrastructure. In fact, the main argument for making large infrastructure investments of this magnitude is to create more effective labor markets connecting "economic islands" into more productive urban regions. The major mechanisms for this cluster upgrading is cluster convergence when a new and larger integrated labor market is created. This is where cluster theory provides an important economic rationale. The predictions from agglomeration and cluster theory are supported by recent research in urban and labor market economics (Behrens, Duranton, and Robert-Nicoud, 2014).

The empirical analysis strongly supports two simple hypotheses: (1) Large industrial clusters outperform small industrial clusters, and (2) Complementary clusters outperform unrelated clusters. Thus, cities and clusters are the two major mechanisms for high productivity economic growth. What our analysis adds to this picture is that excellent infrastructure is an important productivity enhancer given that more effective labor markets and clusters evolve, taking advantage of cluster complementarity. However, infrastructure only works if there is 'something to connect'. Unrelated "economic islands" do not become much stronger if a new highway, fancy new bridges or expensive long tunnels connect them. It takes labor market effects and cluster integration to demonstrate the productivity gains of new infrastructure. Thus, we come back to the importance of critical mass (agglomeration) and the strength of the industrial knowledge base of

industrial clusters. To be even more precise, we should also measure knowledge dynamics of the clusters (Reve *et al.*, 2012), but this has not been done in the current project.

Our data attests to the above conclusions quite clearly. The infrastructure investment over Boknafjorden, connecting the major offshore oil & gas industry cluster of Stavanger with the complementary industrial cluster across the fjord, Haugesund, clearly shows the largest potential economic gains in added value creation, totaling NOK 8.6 billion, using the 10 years phase in model. When we compare the potential gain in value creation to total infrastructure investments, the project turns out to be highly profitable.

Moldefjorden connecting the major maritime offshore cluster of Ålesund with the complementary industrial cluster of Molde, which is also an administrative center, shows the second highest potential gain in value creation, totaling NOK 1.2 billion. Sognefjorden, which connects the two smallest regions with little or no cluster complementarity, only shows potential gains in total value creation of NOK 342 million, which clearly cannot support the large infrastructure investments involved in crossing the spectacular Sognefjorden.

Thus, we can employ the cluster complementarity analyses presented to prioritize large infrastructure projects from an investment point of view. The value added data of our analysis comes in addition to economic gains calculated using traditional transportation economics analyses. Our estimates are conservative, given that cluster growth is set equivalent to average growth in the economy, not taking into account the expected innovative growth factor of dynamic industrial clusters. We further did not add the competitive effects from firm migration. Migration will be more viable following unification further advancing the operation of the direct competition, supplier specialization and advanced customer demand mechanisms.

Clusters do not develop uniformly (Porter, 2008; Zettinig *et al.*, 2012). Materialized gains from connecting 'economic islands' will differ from potential gains. The gap is due to a) the degree

of success in implementing cluster initiatives (Sölvell *et al.*, 2003). This includes the degree of cluster development which requires a challenging balancing exercise between exploitation of current opportunities and the exploration of future opportunities (Zettinig *et al.*, 2012) and firm involvement in clusters (Niu *et al.*, 2012); b) the sophistication and implementation of competitive policies (Ferreira, Garrido Azevedo, and Raposo, 2012; Porter, 2008)

In conclusion, this paper has demonstrated a new theoretical and empirical approach for assessing value creation effects of new infrastructure investments. By relying on traditional transportation economics analyses, the economic effects of major infrastructure investments are typically underestimated. The main drivers for such infrastructural investments are creating more effective labor markets and more attractive industrial regions. Conceptualizing the infrastructure project as connecting 'economic islands' into an integrated and larger labor market, and relying on complete data sets of employees and employers of the two economic entities, give us a unique assessment of the potential increased value creation of the proposed infrastructure investment. While the magnitude of the potential gains is dependent on the degree of cluster complementary and ex-ante differences in productivity between the 'economic islands', the magnitude of gains materialized, due to the degree of convergence, is dependent on public policies and the implementation of cluster initiatives.

References

Almeida, P., Kogut, B. (1999), "Localization of knowledge and the mobility of engineers in regional networks", *Management Science*, Vol. 45 No. 7, pp. 905-917

Arkian, A.T. (2009), "Interfirm knowledge exchange and the knowledge creation capability of clusters", *Academy of Management Review*, Vol. 34 No. 4, pp. 658-676

Behrens, K., Duranton, G., Robert-Nicoud, F. (2014), "Productive cities: Sorting, selection, and agglomeration", *Journal of Political Economy*, Vol. 122 No. 3, pp. 507-553

Bell, G.G. (2005), "Clusters, networks and firm innovatinesness", *Strategic Management Journal*, Vol. 26 No. 3, pp. 287-295

Calem, P.S., Carlino, G.A. (1991), "Urban agglomeration economies in the presence of technical change", *Journal of Urban Economics*, Vol. 29 No. 1, pp. 82-95

Delgado, M., Porter, M.E., Stern, S. (2010a), "Clusters and entrepreneurship", *Journal of Economic Geography*, Vol. 67 No. 1, pp. 150-168

Delgado, M., Porter, M.E., Stern, S. (2010b). Clusters, Convergence, and Economic Performance. National Bureau of Economic Research

European Commission. (2008). Commission decision of 22 October 2008 setting up a European Cluster Policy Group, *Official Journal of the European Union*, Vol. 824/EC:

Ferreira, J., Garrido Azevedo, S., Raposo, M.L. (2012), "Specialization of regional clusters and innovative behavior: a case study", *Competitiveness Review*, Vol. 22 No. 2, pp. 147-169

Giuliani, E. (2007), "The selective nature of knowledge networks in clusters: evidence from the wine industry", *Journal of Economic Geography*, Vol. 7 No. 2, pp. 139-168

Glaeser, E. (2011), *Triumph of the City*, The Penguin Press, New York

Jacobs, J. (1969), *The Economy of Cities*, Penguin Books, London

Jaffe, A.B., Trajtenberg, M., Henderson, R. (1993), "Geographic localization of knowledge spillovers as evidenced by patent citations", *Quarterly Journal of Economics*, Vol. 63 No. 3, pp. 577-598

Marshall, A. (1920), *Principles of Economics* (8th ed.), Macmillan, London

Minken, H. (2013). The economic efficiency of seven projects to eliminate ferry crossings on the E39 highway, Vol. 1272/2013. Institute of transport economics: Oslo, Norway

Niu, K.H., Miles, G., Bach, S., Chinen, K. (2012), "Trust, learning and a firm's involvement in industrial clusters: a conceptual framework", *Competitiveness Review*, Vol. 22 No. 2, pp. 133-146

Norman, E.B., Norman, V.D. (2012). Mørebyen?: Bergen, Norway

Porter, M.E. (1990), *The Competitive Advantage of Nations*, Free Press, New York

Porter, M.E. (1998), "Clusters and the new economics of competition", *Harvard Business Review*, Vol. 76 No. 6, pp. 77-90

Porter, M.E. (2008), *On Competition*, Harvard Business School Publishing, Boston, MA

Reve, T., Sasson, A. (2012), *Et Kunnskapsbasert Norge (Knowledge-Based Norway)*, Universitetsforlaget, Oslo, Norway

Sorenson, O., Audia, P.G. (2000), "The social structure of entrepreneurial activity: Geographic concentration of footwear production in the United States, 1940-1989", *American Journal of Sociology*, Vol. 106 No. 2, pp. 424-462

Sölvell, Ö., Lindqvist, G., Ketels, C. (2003), *The Cluster Initiative Greenbook*, Ivory Tower Stockholm

Tellman, S., Jenkins, M., Henry, N., Pinch, S. (2004), "Knowledge, clusters and competitive advantage", *Academy of Management Review*, Vol. 29 No. 2, pp. 258-271

Venables, A.J. (2007), "Evaluating urban transport improvements: Cost-benefit analysis in the presence of agglomeration and income taxation", *Journal of Transport Economics and Policy*, Vol. 41 No. 2, pp. 173-188

Wilson, T.L., Lindbergh, L., Graff, J. (2014), "The Competitive Advantage of Nations 20 years later: the cases of Sweden, South Korea and the USA", *Competitiveness Review*, Vol. 24 No. 4, pp. 306-331

Zaheer, S., Lamin, A., Subramani, M. (2009), "Cluster capabilities or ethnic ties? Location choice by foreign and domestic entrants in the services offshoring industry in India", *Journal of International Business Studies*, Vol. 40 No. 6, pp. 944-968

Zettinig, P., Vincze, Z. (2012), "How clusters evolve", *Competitiveness Review*, Vol. 22 No. 2, pp. 110-132

Table 1: Highest education level achieved by regions, 2011

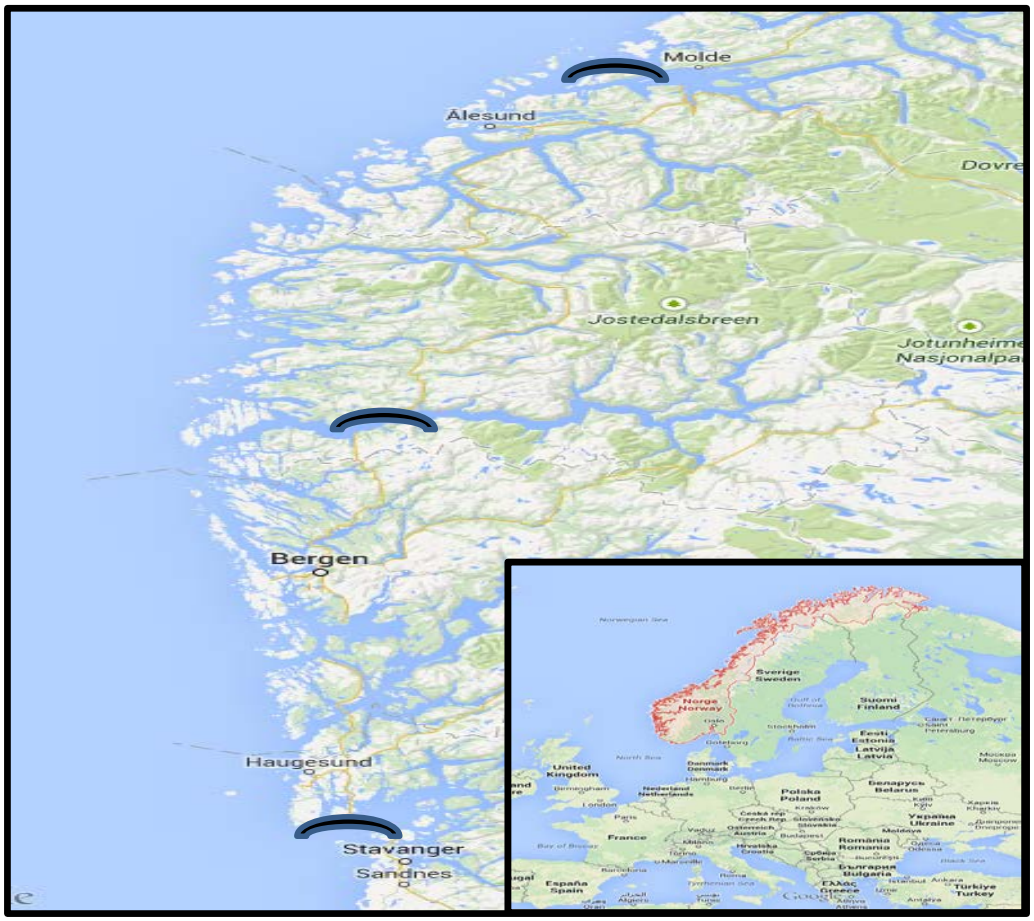
	Stavanger	Haugesund	Ålesund	Molde	Løvik	Oppedal
Secondary School	23%	24%	28%	29%	25%	27%
High School	46%	53%	51%	53%	49%	58%
Bachelor Degree	21%	19%	18%	15%	22%	12%
Master Degree	9%	4%	3%	4%	4%	3%
PhD	1%	0%	0%	0%	0%	0%

Table 2: Annual added value, by crossing

	Immediate process	10-years process		
	Value creation	Value creation	Added value creation per employee (NOK)	Value creation/ infrastructure cost
Boknafjorden	17,237	8,565	113,168	71%
Moldefjorden	2,314	1,178	59,094	9%
Sognefjorden	704	342	48,094	2%

Note: Values in NOK millions

Figure 1: Map of E39 and fjord crossings



The small map on the right hand side indicates the location of Norway within Europe. The larger map is of the West Coast region of Norway. Arches depict the three fjord crossings discussed in this paper. The arch in the bottom indicates the location of the Stavanger-Haugesund crossing over Boknafjorden (Bokna fjord), in the middle the Løvik and Oppedal crossing over Sognefjorden (Sogn fjord), and at the top the Ålesund-Molde crossing over Moldefjorden (Molde fjord).

Figure 2: Value creation per employee over a 10-year period

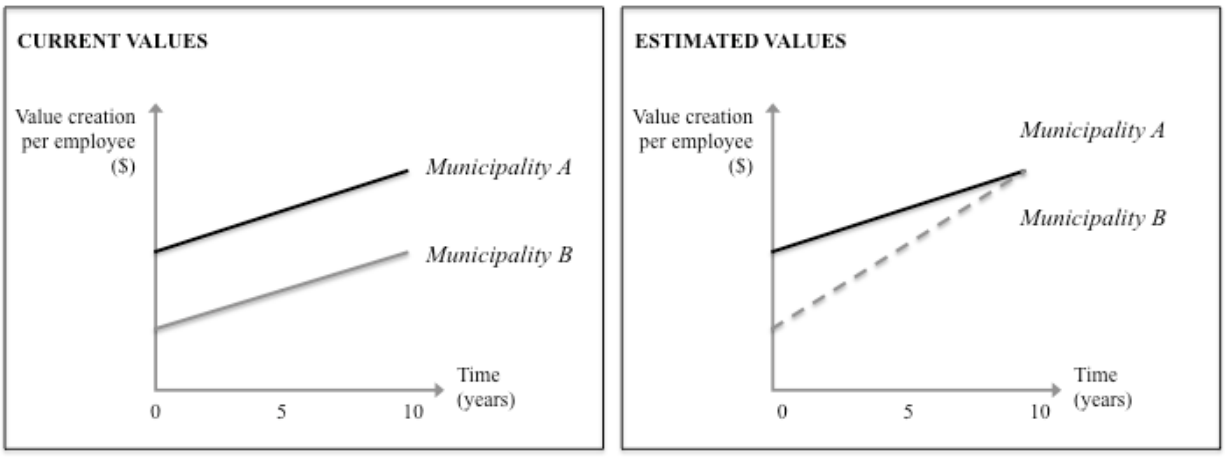


Figure 3: Value Creation in an industry