Domestic and Cross-Border Accessibility Spurring Agglomeration Economies in Regional Employment: The Case of European Transport Policy

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Abstract

We study the relationship between infrastructure investment in ten West European countries, as represented by accessibility enhancements, and the level of regional employment. Regions are expressed at the European NUTS-3 level. Following the core-periphery model, we interact accessibility with the categorical regional typology of urban-intermediate-rural. We distinguish between domestic and cross-border accessibility, thereby examining European transportation policy from these two different angles. For the period 2000-2016, we run several regression analyses incorporating fixed effects to establish the causal relationship between accessibility and employment, in which the latter is measured as an aggregate as well as separated into economic sectors. The claim of causality is strengthened by a robustness control that makes use of a two-stage least squares analysis, in which we instrument regional domestic accessibility with historical trade route accessibility from the Middle Ages. We find that higher domestic accessibility levels spur higher regional employment density across European regions, with little distinction between region types. For cross-border accessibility, impacts vary from positive for urban regions to negative for rural regions. Changes in sectoral composition and regional differences in specialization are at least partly driven by accessibility changes. We identify spillover effects across regions, most of which establish negative backwash effects between peripheral (rural) regions and core (urban) regions.

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1. Introduction

One of the major policy portfolios of the European Union (EU) covers infrastructure and regional accessibility. It has been an important tool in order to achieve regional growth and convergence, and it will continue to play this role in the future, with an ever increasing budget made available each budget period for European infrastructure projects, especially those which fall within the Trans-European Transport Network (TEN-T) framework. Such projects aim to enhance regional accessibility within countries, on the one hand, and on the other they aim to connect regions across national borders in order to strengthen the EU internal market. The investments in new and upgraded infrastructure are premised on the reasoning that better accessible regions have a wider market access, due to which they have a better position to grow. This improvement of the general connectivity within the spatial economy allows so-called agglomeration economies (positive productivity externalities from economic clustering) to operate over a larger geographical distance as producers are able to target broader markets (Graham and Melo, 2011; Lakshmanan, 2011). The latter effect plays an important role in the theories of New Economic Geography (NEG) which predict that, as the economies of different regions become better linked, there is increasing specialization in production and trade, resulting in an increase in regional productivity. This can affect several further economic factors, including employment (both aggregate employment as well as its distribution across sectors) and income growth.

Following the strong theoretical arguments in favour of infrastructure investments, accessibility enhancements in the EU have been significant over the past decades (Gutiérrez, 2001; Gutiérrez and Urbano, 1996; Ibáñez and Rotoli, 2017; Spiekermann and Wegener, 2006, 1996; Vickerman et al., 1999), especially in urban areas (Spiekermann and Wegener, 1996). There is a wide range of literature studying the regional growth effects of such accessibility changes. The majority of empirical studies finds a positive effect of infrastructure enhancement and accessibility improvement on regional growth, expressed i.a. in terms of GDP (Bröcker and Schneekloth, 2005; Spiekermann and Wegener, 2006), firm growth (Holl, 2004; Holl, 2006) or population size (Batista e Silva et al., 2013). However, there are also those who argue that infrastructure projects have no economic effects beyond the direct effect of lowering transportation costs (Banister and Thurstain-Goodwin, 2011). And, when separating cross-border accessibility in Europe from domestic accessibility, Jacobs-Crisioni and Koomen (2017) find that cross-border accessibility did not induce regional growth of population. Taking population as a proxy for regional economic growth, this result casts doubt of the regional growth effects of cross-border infrastructure and the integration of local markets as envisioned in EU transport policy. As such, in the specific case of European transport policy, it remains difficult to know which exact effects are at play.

European transport policy was largely based on the argument that national borders act as barriers to transport. In addition, remote and border regions as well as rural regions falling between the main transport nodes would be as a disadvantage. This would especially make regions in peripheral EU countries vulnerable. Infrastructure investment, therefore, is seen as an important tool in the EU cohesion objective (Witte et al., 2014, 2013), spurring regional income growth and encouraging employment to grow. This goal was to be reached by connecting previously detached national infrastructure networks and improving cross-border connections, enhancing network efficiency, removing bottlenecks, overcoming technical barriers and extending infrastructure into peripheral and rural regions, where accessibility was lagging (Ibáñez and Rotoli, 2017). Vast amounts of money have been injected into such projects, for instance under the TEN-T policy. Jacobs-Crisioni and Koomen (2017) show cross-border accessibility has been growing more than domestic accessibility since the 1960s, at least in West-Europe.

EU infrastructure policy was also to contribute to completing the internal market and enhancing overall EU competitiveness among global forces (Peters, 2003). However, several researchers, including Peters, have now shown that this array of objectives at least partly conflict one another, with especially the cohesion goal being in jeopardy. The majority of evidence on the European transport network presented in the present paper proves accessibility increases were highest in already central regions - including urban areas and regions in the European core countries. This has a significant impact on the spatial distribution of any growth effects brought about by the network's construction, including agglomeration effects. In addition, even equal accessibility enhancements are still likely to affect central regions most, because through economies of scale the process favours the already well-performing locations (Lakshmanan, 2011). Philippe Martin (1999, p. 12) argues that it is exactly the reinforcing of agglomerated regions (an anti-cohesion effect), along with encouraging specialization between regions, which enhances efficiency and competitiveness at a pan-European level. As such, expanding the existing knowledge on the distributive effects of the European network is highly relevant in order to judge which of its objectives have so far been achieved, and what this has done for economic efficiency. That is what the present paper will aim to achieve.

We will investigate the claim underlying EU transport policy, that the investments enhance regional growth. We focus on regional employment. This is done within the framework of the Wider Economic Impact (WEI) of infrastructure and one of its main components: the effect of accessibility changes on location choices, economic clustering and agglomeration economies. Agglomeration can be measured in different ways, and we will concentrate our measurements on so-called localization economies: clustering of economic activities, expressed in the employment size and specialization of different sectors. We distinguish between domestic and cross-border accessibility changes, in order to come to a more comprehensive understanding of accessibility effects on European regions. We study the following main research question:

> *How has investing in the European infrastructure network, and the subsequent regional domestic and cross-border accessibility enhancement, affected localization economies - measured as employment density - in European NUTS-3 regions?*

We make use of accessibility data made available by Jacobs-Crisioni and Koomen (2017), which measure ten-year domestic and cross-border accessibility for ten West-European countries between 1961 and 2011. We build on Jacobs-Crisioni and Koomen's research on municipality population growth effects by studying regional employment effects. Employment is aggregated as well as measured per sector, due to which we can distinguish between effects for different sectors, and also draw conclusions on regional specialization changes. The effects are separated into those observed for urban, rural and intermediate regions. Lastly, spillover effects between regions are measured. The results, found by applying fixed-effects panel data regression analysis, can be used to draw conclusions on the impact of domestic and cross-border accessibility, as well as the differences between the two. The necessary assumption is that the effects we find are causal. As such, we will apply different methods and controls of robustness, including an instrumental two-stage least squares analysis, to strengthen the claim of causality. With causal effects found, this paper aims to fill the gap in the literature where WEI of infrastructure are claimed to exist for international infrastructure networks. Our contribution is to add to the existing knowledge on the micro-level regional impacts of infrastructure improvements. This has a scientific use as well a political one: reflecting on the past impact of accessibility changes, and informing decisions regarding future expansion of the European transport network. In addition, studying accessibility growth effects can add to the limited literature on the cohesion effects of European infrastructure and regional growth policy.

This paper is structured as follows. Chapter two presents the theoretical framework and an overview of previous empirical findings at the end, after which we identify a research gap, and the research questions follow. In chapter three, we lay out the methods used to answer the research questions. We present the regression models, their specifications, the data used, some descriptive statistics, and maps with a geographical representation of the most important measurements. Chapter four then presents the empirical results, robustness controls and answers to the research questions. Finally, chapter five gives the conclusion of this paper.

2. Theoretical Framework

In this chapter, we present theoretical and empirical studies which link infrastructure networks and accessibility enhancements to the growth of those regions being connected. We will first look at regional accessibility in a more general context. The focus will be on the accessibility changes that have taken place in Europe over the last few decades. After that, we will build a framework that helps predict what the regional (employment) growth effects of such accessibility changes might have been. This framework relies on the theories of New Economic Geography, the core-periphery model and agglomeration economies. We provide a short summary of empirical findings at the end of this chapter, before we come to our specific research (sub-)questions.

2.1. Accessibility over the European Transport Network

As Vickerman (2018) stresses: "*The key to understanding the economic impact of transport is in understanding the role of accessibility"* (p. 32). The effect of infrastructure enhancements on accessibility is widely analyzed in the literature. So is the consequent effect of accessibility on regional development. Various definitions of accessibility are used within that literature, but most come down to the following: *"Some measure of spatial separation of human activities, which denotes the ease with which activities may be reached using a particular transportation system"* (López et al., 2008, p. 280). The more comprehensive accessibility measures hence reflect the connectivity of transport networks as a whole by not only representing the networks themselves, but also the activities, opportunities and population that can be reached by it (Spiekermann and Wegener, 2006). To understand the regional economic effects of the European transport network, we must first understand its impact on regional accessibility.

The European transport network is maintained at different jurisdictional levels. The largest investments are done at the EU level, with billions of Euros flowing into upgrades and extensions of the network each budget period. These funds regard the so-called core corridors and what is called the comprehensive network. Included are railway lines, roads, inland waterways, maritime ports, airports and rail-road terminals. Of these modes, the former two make up the largest and most important part of the network. Today, especially the role taken on by high-speed rail transport is significant, with the majority of funds flowing into railway projects (Puga, 2002). Both infrastructure types - railway and motorways - are aimed at goods transportation as well as personal commuting. The intention of the part of the network that is overseen by the EU is to provide missing links, reduce bottlenecks, and increase regional accessibility, thereby inducing regional economic growth, not just in the urban areas that serve as the network's nodes, but also and especially in rural regions and countries in the EU's periphery, where accessibility has traditionally been lagging. Due to its cross-border nature, the network connects regions both within national borders as on opposite side of borders. As such, it contributes to enhancing domestic as well as international accessibility (Ibáñez and Rotoli, 2017).

There is general agreement in the literature that the EU investments in the network have indeed significantly increased accessibility in European regions over the last decades (Batista e Silva et al., 2013; Gutiérrez and Urbano, 1996; Ibáñez and Rotoli, 2017; Stępniak and Rosik, 2018). While this was the primary objective of the policies in place since the 1990s, it is still noteworthy, due to the widespread belief that infrastructure networks in developed countries such as the EU members are already so advanced that additional links will only have a marginal or even negligible impact on the accessibility in the system as a whole (Banister and Berechman, 2001). Yet, this is generally not the case when it concerns a major change in the system-wide accessibility, e.g. a new link joining two previously disjoint networks, or the opening up of a previously inaccessible location. This has clearly been the case for the European network.

The fact that the European transport network was largely effective in increasing regional accessibility does not mean that all regions benefited equally, or even benefited at all. This is true for accessibility effects, but also for regional economic effects, to which we will turn in the following chapter. For accessibility, what matters most is the distinction between absolute and relative accessibility gains. While the network enhanced absolute accessibility levels in most European regions, it impacted some regions much more than others, leading to relative gains in those regions, and relative losses in others. Spiekermann and Wegener (1996) and Vickerman and co-authors (1999) show this for the TEN-T's rail network once it would be completed, and conclude that relative accessibility gains of cities in the European core are several times larger than those of cities at the European periphery, and city gains are significantly larger than those felt in rural areas. Gutierrez and Urbano (1996) show a similar result for the TEN-T road network, although the effect is less pronounced, and there is some evidence that the road network did affect peripheral and lagging regions most, at least when looking at absolute gains over time (Batista e Silva et al., 2013; Ibáñez and Rotoli, 2017). Batista e Silva and co-authors do stress that improvements in accessibility found do not change the ranking concerning which member states have the highest levels of accessibility; core countries retain their advantage vis-à-vis peripheral countries.

Although there is some disagreement on the relative gains for central versus peripheral EU regions and urban versus rural areas, it becomes clear from the literature that core urban regions benefited most in terms of accessibility gains. However, previous research points out there are important gains besides accessibility improvements and the corresponding transport cost reductions and efficiency gains in the movement of goods and people. Such benefits are commonly referred to as the Wider Economic Impact (WEI) of transport infrastructure investment. It is this impact that the present paper is most interested in, because - as we will see - it contributes to a variety of factors which in turn determine agglomeration potential. The following chapter will therefore focus on how transport infrastructure in general and the European network in particular can bring WEI to (urban) regions.

2.2. Regional Development, Wider Economic Impact and Agglomeration

Accessibility improvements are sometimes seen as an ultimate goal, where accessibility proxies welfare by its nature of reflecting the access individuals have to essential services. However, more often it is viewed as a means, rather than an end: a way to improve upon economic activity and social cohesion (López et al., 2008). Better accessible places have a competitive advantage over those relatively less accessible, by lowering transport costs, making industries more competitive and improving the internal as well as external linkages of a market. The market potential of a place thus strongly depends on its role in a network; its centrality with respect to alternative sites and markets (Ottaviano, 2008). Improving the efficiency of the network contributes to productivity growth and can, finally, also have an impact on regional economic (GDP) growth. This is the major goal underlying the European network (Crescenzi and Rodríguez-Pose, 2008). However, as Banister and Berechman (2001) stress, this generally does require the presence of several conditions which insure the infrastructure investment can be translated into regional economic benefits with a multiplier effect beyond the transport construction phase benefits. Such factors include an underlying structure of positive economic externalities, investment factors (i.a. the availability of funds for the investment, the scale of the investment and its location, the network effect), and political factors, such as the presence of supporting legal, organisational and institutional policies and processes.

When the factors mentioned in the preceding paragraph are present, infrastructure investments can lead to a Wider Economic Impact (WEI). This refers to more than just regional GDP effects; an entire economic structure can change, including the labour market and regional sectoral specialization (Banister and Thurstain-Goodwin, 2011). Evidence for such effects for the European infrastructure network seem to be scarce. There is some evidence from studies done for the EU's Cohesion Fund, that it has a positive correlation to private business investment (Peters, 2003). This suggests a positive effect on employment growth in the long run, although there is no evidence on where this growth would accrue. A rather different picture emerges from the study done by Jacobs-Crisioni and Koomen (2017), who show that cross-border accessibility has not had much effect on regional population and economic growth. Specifically for the TEN-T network, only the distribution of GDP effects has received extensive attention in empirical analyses. Previous works have shown that TEN-T's large accessibility impact likely did lead to regional GDP growth, at least for some EU regions, although the effect observed in empirical studies is rather low, and there might have been negative growth effects in regions which gained little or nothing in accessibility (Bröcker and Schneekloth, 2005; Spiekermann and Wegener, 2006). The exact dynamics linking infrastructure to regional growth are rather complex, due to strongly varying spatial factors. In the following sections, we will examine the literature on WEIs for general infrastructure cases, in order to link predictions to the European-wide case.

2.2.1. Wider Economic Impact

A point of criticism often brought forward when evaluating transport infrastructure investments is the claim that efficiency and accessibility enhancements only redistribute economic activity, instead of creating new activities and growth, thereby having little impact beyond the transport effects of relieving existing infrastructure (Banister and Thurstain-Goodwin, 2011). To validate investments in infrastructure projects, policy-makers therefore often point at the Wider Economic Impact for regions connected to the network and the potential for positive spillovers to the regions surrounding those directly connected (Holl, 2006). WEI refers to those effects not included in traditional cost-benefit analysis, which only looks at economic benefits to households and firms by calculating changes in generalized travel costs, composed principally by time savings, savings in vehicle operating costs, and improved safety. The wider, more indirect effect can transpire if markets are not perfectly competitive and/or direct transportation user benefits are not fully specified. Conditions which are rather easily met, considering space itself introduces the necessary and sufficient conditions for imperfect competition and location externalities: product differentiation; uncertainty; and imperfect knowledge (Holl, 2006). In that case, WEIs can be substantial, and emerge at various levels of the economy. Banister & Thurstain-Goodwin (2011) identify the macro, meso and micro level. Macro refers to regional economic (GDP growth). Meso refers to agglomeration economies resulting from spatial clustering of firms and people, labour market economies, network economies, but also negative environmental externalities play a role at the meso level. In addition, employment effects can be substantial, with productivity gains for existing jobs as well as the creation of new jobs. At the micro level, important factors include land and property values.

The three levels identified by Banister and Thurstain-Goodwin somewhat coincide with the short-, medium- and long-term analyses proposed by other authors, such as Blum et al (1997). Most relevant for the present analysis is the medium term, in which new transport infrastructure and accessibility changes induce people and firms to relocate, a process likely to lead to urbanization. There is also the possibility of firms relocating to smaller regions within the transportation corridor, which are now better connected. These firms can come from within or outside the corridor. In the case of the European network, firms are likely to move from rural areas in the EU to the corridor regions (especially the larger cities). It can even lead firms from outside the EU to relocate to corridor regions to gain from the internal market, which now has the addition benefit of better internal transportation infrastructure.

Because improvements in infrastructure lower transport cost barriers to competition, investments can also force the exit of low-productivity firms which were previously protected from outside competition (Gibbons et al., 2012). This leads to long-run increases in aggregate productivity. In the case of international transportation infrastructure, this can mean increased competition from foreign (other EU) firms. Although such productivity gains are beneficial for a region, not all regions are equally equipped to withstand and gain from stronger outside competitive forces. If a poorer region is connected to richer regions, such as those in the EU North-Western core countries, firms in the poorer region do get access to the inputs and markets from the more developed regions, but the connection can also harm the economy of the poorer region by allowing the more developed regions to supply the lagging region at a distance (Puga, 2002). This is especially an important issue for the pan-European network, due to the large differences between EU regions in the core and periphery. The potential for regions to benefit from Wider Economic Benefits of infrastructure investment, therefore, is far from homogeneous.

The existence and significance of WEI is not undisputed, however, and the discussion is ongoing in economic and transportation literature. Rothergatter (2005, p. 132) argues as follows, "*Neglecting WEI of large projects and comprehensive investment programmes increases the risk of overlooking* *the challenges to modernising the transport system and to adjusting it to the changing future needs of society and industries".* Rothergatter highlights that this is the case for the trans-European network and its strategic design, not only because of its large scale but also because of its cross-border nature. Transport volumes in border regions have traditionally been low due to the physical and psychological barrier imposed by national borders. Even in the EU, where the internal market has been established to minimize border effects, such barriers remain in place as language, legislation and cultural differences do not easily erode (Jacobs-Crisioni and Koomen, 2017). The resulting low volumes of transport in border regions, combined with the fact that benefits of investing in one region are not contained within that region, make investment in additional infrastructure there look unprofitable when applying conventional cost-benefit analysis. This justifies paying attention to the trans-European network's Wider Economic Impact. While there are authors who argue the WEI of infrastructure on its own is limited (Banister and Berechman, 2001) and there is some empirical evidence supporting this (Gerritse and Arribas-Bel, 2018; Graham and Melo, 2011), the evidence supporting the existence and significance of WEI is much larger (e.g. Banister and Thurstain-Goodwin, 2011; Carbo et al., 2019; Gibbons et al., 2012). Probably the most accurate conclusion is provided by Blanquart and Koning (2017) in their review of local economic effects, who comment that results show great variability as many conditional factors, including urban distance and size and industry structure, are at play.

The literature on WEI from infrastructure investment highlights the role played by agglomeration economies (Cheng et al., 2015). Cities, thus, form important entities when it comes to the regional impact of infrastructure. The framework underlying why this is the case comes from New Economic Geography theory. As such, the following section will explore this topic, before we turn to the agglomeration effects of infrastructure, and the expectations this brings for the European case.

2.2.2. New Economic Geography and the Core-Periphery Model

Puga (2002) provides a comprehensive overview of the core-periphery model in New Economic Geography (NEG) theory, which was brought forward by Krugman (1991). This section will only briefly touch upon the topic, because it provides the basis for infrastructure-induced agglomeration effects. The central premise of the model is that transport costs form the balancing factor between forces drawing firms and people towards cities (centripetal forces) and those driving people and firms outside cities (centrifugal forces). Lower transport costs created by i.a. infrastructure investments will generally lead to a core-periphery pattern in the economic geographic landscape: cities and hinterlands will form, and the accessibility improvements will favour cities and their growth. In initial versions of the model, the clustering process depended on labour migration across regions, in addition to increasing returns and the presence of trade costs. However, later applications of the model showed it can hold when labour mobility is low. This is exactly the result relevant for the present paper, because labour mobility between European regions across national borders is low (Puga, 2008). The core-periphery model and its prediction of economic clustering holds because firms can still benefit from being close to each other. They gain from dense labour markets and knowledge sharing (the agglomeration economies described in the next section), as well as from direct input-output linkages.

The question is whether the model and its predictions are applicable to the cross-border European network. This indeed seems to be the case. The NEG models were constructed on a regional level, and this can be in an international setting where transport costs are basically interregional trade costs. The

European transport network can then be seen as infrastructure reducing border effects and transport (trade) costs, comparable to the scenario of EU integration. This is supported by various authors who use the core-periphery model to base prediction for the network's effect on urban regions on. Pol (2003) argues that very similar mechanisms to the ones described in the paragraph above are applicable to the hierarchy of European urban areas. Vickerman (2018) links the core-periphery effect to infrastructure investment that can cross national borders, and the TEN-T railway network in particular.

Although we can apply the predictions of the core-periphery model to the trans-European network, this does not mean that its construction automatically leads to further urcan concentration. The model also leaves the possibility of economic dispersion, which occurs when transportation costs fall below such a low level that physical proximity to markets no longer matters. Firms, who face increased competition along with rising negative externalities of high concentration, might then move away from urban areas to take advantage of lower wages and land prices. This may give rise to a bell-shaped relation between transport costs and concentration (Puga, 2008; Thisse, 2009). We would observe dispersion forces in the EU when transportation costs were already extremely low before works within the EU transport policy began. Some indeed argue that the marginal effect of the EU investments on accessibility and transport costs was likely to be negligible because the European network was already highly advanced when such investments were done in the 1990s and the 21st century. However, we have seen considerable accessibility changes (Ibáñez and Rotoli, 2017; Spiekermann and Wegener, 1996), and the EU network is built up of links that close gaps between national networks, because of which we can also argue transport costs were still significant before the more recent investments were done.

When the EU transport policies and the resulting network changes indeed reinforced the urbanization process, other forces can take over. The concept of growth-poles predicts that economic growth manifests itself at different intensities in concentration points, which is the created core of urban areas (Pol, 2003). Some authors argue that growth can subsequently spread to surrounding regions and create positive growth effects - infrastructure spillovers (Vickerman, 1996). However, more recently, significantly more support and evidence for the opposite has arisen, namely negative backwash effects for less connected, peripheral regions, who loose their labour and capital to the growth poles (Peters, 2003). It are the bigger economic centers - the cities - who benefit from this (Vickerman, 1996). When economic growth induced by infrastructure investment concentrates in cities and firms and workers (and thus, employment) cluster there, the basis for the the reinforcement of agglomeration potential is created.

2.2.3. Agglomeration Effects

As we have seen, infrastructure investment can lead to economic concentration and a core-periphery structure or, when already present, either to a reinforcement of weakening of this geographic pattern. The potential for agglomeration economies can, therefore, also move in either direction: increase or decrease.

Agglomeration effects are external economies or positive externalities resulting from the spatial concentration of economic activity (Graham, 2007). While different types can be identified, the two most important ones are urbanization and localization economies (Witte et al., 2014). The former refers to benefits from shere proximity to other economic activity within a city, e.g. input-output sharing and access to urban amenities such as R&D departments. It is often represented by a measure of scale of a location, such as the size of a city, its population or employment. Localization economies refer to the concentration of certain industries and the pooling of their labour market, the sharing of intermediates and technological spillovers resulting from the sharing of knowledge. In literature, it is often modelled as industry (employment) density or scale, or an industrial specialization index. Agglomeration effects can lead to productivity enhancement (Sveikauskas, 1975), which in turn increase economic growth in the agglomeration region.

This paper already mentioned that infrastructure improvements can induce firms and people to move by leading to changes in the optimal location of activities, and it mentioned how urban areas are likely to play the largest part in this phenomenon. It is this development of population enlargement and the concentration of economic activity which strengthens agglomeration (Duranton and Turner, 2012). The process of the location decision is shortly explained here. For individuals, the cost-benefit relation changes in favour of some more accessible places. Interestingly, as the monocentric city model explains, this can also lead to a draw away from city centers towards the urban fringe, where land prices are lower, which could in fact weaken agglomeration in the urbanization pillar (Baum-Snow, 2007). Firms, on the other hand, choose the location that maximizes their market potential, and as the previous section describes this involves a trade-off between agglomeration and dispersion forces (Blanquart and Koning, 2017). As Vickerman (2018) explains, this relocation process, that leads to faster employment growth in some areas and slower in others, is the potential for agglomeration effects to occur. However, on a larger scale (e.g. the EU or member state scale), the movement of mobile resources only generates new economic development if it creates addition inter-firm linkages compared to the initial situation (McCann and Shefer, 2004).

Not all analysts are in agreement when it comes to the importance of transport infrastructure and accessibility as a location factor. With ever decreasing transport costs, the role of non-material flows becoming larger and a network that can already be considered dense, the impact of infrastructure in the traditional sense of transportation might actually be small (Banister and Berechman, 2001). On the other hand, there is also evidence that location also matters for things other than transport, such as sharing of resources, matching of workers to firms, and learning by information exchange (Duranton and Puga, 2003). This argument is in line with the distinction made by Chatmand and Noland (2011) between internal and external agglomeration economies. The former refers to firms seeking larger market areas that enable the realization of internal economies of scale in production, and the latter refers to the sharing, matching and learning mechanisms identified by Duranton and Turner. Both are relevant for the occurence of agglomeration and productivity effects. External agglomeration economies are especially relevant for the link between railways and agglomeration, and the high-speed rail network in particular, because of its focus on transportation of persons instead of goods. Moreover, high-speed rail can release capacity on the existing infrastructure links, enhancing their efficiency (Cheng et al., 2015). Graham and Melo (2011) argue that we can extent the agglomeration arguments made for WEIs for intra-urban infrastructure to inter-urban investments for high-speed rail investment, because the basic argument for agglomeration holds: "I*f spatial interactions between economic agents are made more efficient then increasing returns can be expected"* (p. 18).

So, as the previous paragraph explains, a movement of firms and economic activity is not the only contributor to agglomeration potential. Transport infrastructure improvements can also increase the strength of agglomeration economies by increasing connectivity within the spatial economy (Graham and Melo, 2011), whether it be within a city or between cities. For even though the agglomeration literature generally takes individual cities as the locus for such effects, they can also take place between cities within a transportation network (Johansson and Quigley, 2004). In fact, Witte et al (2013) explain how an integrated network of urban areas in Europe (the "necklace of cities") is what drives agglomeration externalities over distance, rather than just transport corridors. Agglomeration effects do tend to decrease with distance (Puga, 2008), but it is exactly the effect of investing in a large-scale network such as the EU's that effectively reduces this 'distance', because in the setting of agglomeration economies, distance is better described as transportation, travel and interaction distance than as a physical distance.

With the theoretical relation between accessibility changes and agglomeration established, we can make more precise predictions for the effects on regional economic activity; especially, its composition within as well as across regions. As Chandra and Thompson (2000) show for the United States, the relation between infrastructure investment and economic activity differs across industries, and it also differs across regions, mainly depending on how well a region is serviced by new infrastructure. Such new infrastructure thus affects the spatial allocation of economic activity. The main result from Chandra and Thompson is that some industries (measured as total industry worker earnings) will grow as a result of accessibility enhancements, while other industries will shrink. The authors conclude this after controlling for general trends in industrial composition resulting from e.g. national business cycles, changes in labour productivity in different sectors and changing demand patterns. This result is an important one when we are examining agglomeration economies, because the strength of such economies depends not only on the total size of economic activity, but also strongly on regional sectoral composition. Chandra and Thompson's result, however, still needs to be verified for the EU case, and any industry factors beyond worker earnings.

2.2.4. Empirical Results

From the previous analysis, it becomes clear that infrastructure investments *can* have a profound effect on agglomeration potential, but also that agglomeration effects vary widely in occurrence and ways of functioning. In general, one can say that transportation infrastructure enables agglomeration effects to happen when it affects the underlying variables; i.a. population density, city size, employment concentration. Graham (2007), for instance, takes as given the fact that transportation investment increases the effective density of economic activities. The author consequently shows that there are positive externalities (increase in total factor productivity) from increasing urban densities and that these can be substantial, particularly for service industries. Sveikauskas (1975) also shows that increasing city (population) size is associated with a significant increase in labour productivity. However, this is one specific result. Witte et al (2014) provide conflicting evidence that urban density does not increase productivity or agglomeration effects, whether inside or outside the European infrastructure corridors. The authors stress that productivity increases in urban areas are hard to achieve because productivity levels are already significantly higher, in general. Moreover, even when the relationship between infrastructure and urban (economic) density is established for a specific link or network, it is no guarantee that agglomeration effects and the accompanying productivity gains really occur. We can, therefore, see the search for the effect of an infrastructure network such as the

EU's on the variables underlying agglomeration as an exercise to examine agglomeration *potential*. To gain an understanding of the precise effect between infrastructure investment and the agglomeration variables, what follows is a (non-comprehensive) overview of empirical results within this area. Such an overview also enables a better judgement of gaps in the literature.

Table 1. Review of Empirical Results

Paper	**Relation**	**Study Area**	**Result**
(Boarnet, 1980)	Road infrastructure → Output	U.S.	A positive relation is found, although there is a backwash effect (output reduction) in adjacent regions.
(Chandra and Thompson, 2000)	Road infrastructure → Industry worker earnings (as a proxy for value-added output)	U.S.	Infrastructure investment is positive for some industries (e.g. manufacturing) and negative for others (e.g. farming), as economic activity relocates to other industries and other places. A direct connection to the infrastructure has a positive effect on a region, and there is a backwash effect in surrounding regions.
(Holl, 2004)	Road infrastructure → New manufacturing establishment	Spain	New motorways affect the spatial distribution of manufacturing establishments at the municipality level. They attract firms, with negative spillover effects for more remote locations.
(Bröcker and Schneekloth, 2005)	TEN-T network implementation → GDP & GDP per capita	E.U.	Positive but low gains from TEN-T implementation for regional GDP. With the relative neutrality assumptions [percentage change in GDPpc], cohesion is improved, but when looking at absolute neutrality [absolute gains], the network is anti-cohesion.
(Spiekermann and Wegener, 2006)	TEN-T rail investment → GDP per capita	E.U.	TEN-T has a relatively large effect on regional accessibility, but this translates only into low GDPpc gains.
(Baum-Snow, 2007)	Road infrastructure → Population & land use	U.S.	Radial interstate highways passing through a city reduce central city population as people move towards the suburbs.
(Crescenzi and Rodríguez-Pose, 2008)	Road infrastructure → GDP per capita	E.U.	The local total endowment of transport infrastructure is an important and robust predictor of economic growth. However, the annual change in infrastructure endowment is not significant for the EU-15 and has a negative and significant coefficient for the EU-25.
(Graham and Melo, 2011)	Rail infrastructure → Agglomeration benefits	Great-Britain	Evidence on the spatial distribution of commuting and business flows shows a considerable impact on long-distance (inter-city) interactions from high-speed rail investment, especially for business interactions.
(Duranton and Turner, 2012)	Road infrastructure → Population & employment	U.S.	An increase in a city's stock of roads causes a small increase in its population and employment.
(Gibbons et al., 2012)	Road infrastructure → Employment, labour productivity, gross value added, revenues & average wages	Great-Britain	Positive effects for total employment, resulting not from existing firms but from new firm inflow. Positive effects on labour productivity, gross value added, revenues and average wages.
(Batista e Silva et al., 2013)	EU Cohesion infrastructure → Land use & population	E.U.	Accessibility improvements cause a shift of urbanization closer to cities, where accessibility levels are the highest. This comes at the cost of more rapid de-urbanization in remote areas. The shift of urbanization towards cities is the strongest in compact growth policy scenario, where urban

			development is only allowed in the proximity of existing population centres.
(Cheng et al., 2015)	Railway infrastructure → Employment	China & E.U.	Results for employment growth differ between high-speed rail cities but are generally positive, and higher in core cities compared to their hinterland.
(Percoco, 2016)	Road infrastructure → Firm location, employment & population	Italy	An increase in accessibility due to road investments caused an increase in the employment growth rate.
(Yu et al., 2016)	Road infrastructure → Economic concentration	China	An improvement in the motorway network leads to a higher degree of geographic concentration of economic activities. However, new motorway construction facilitated spatial dispersal when transport costs fell below a critical level. Moreover, the improved road network has led to a loss of industry in lagging areas.
(Jacobs-Crisioni and Koomen, 2017)	Cross-border accessibility → Population density changes	North-West Europe	Municipal population growth (proxying local economic activity) has depended almost exclusively on domestic market access, and not on cross-border accessibility.
(Wetwitoo and Kato, 2017)	Rail infrastructure → Agglomeration (employment size) & economic productivity	Japan	Regions with HSR stations have higher economic productivity and agglomeration.
(Carbo et al., 2019)	Rail infrastructure → labour productivity, gross value added, number of firms & employment	Spain	Positive and significant impacts from HSR on labour productivity, on economic output (i.e gross value added), and on numbers of firms. There were no significant effects on employment on a provincial level.

The overview in the table above shows how infrastructure generally has a positive impact on regional economic development *in those regions where the infrastructure is located and we find the highest accessibility impact.* Regions where such infrastructure investments do not land are often found to be at a disadvantage, which is in line with the predictions made for backwash effects. Railway networks, especially, tend to exhibit this effect. It contradicts the claim made by some of the papers presented in the previous section that infrastructure has a positive spillovers effect even in regions further away from the network. The literature is in agreement that urban areas stand to gain the most, both in terms of absolute accessibility improvements as well as in terms of its impact on urban population and economic activity. As such, urban areas that receive an accessibility boost are likely to attract even more firms and people. Existing firms as well as new ones potentially enjoy productivity gains resulting from the network extension. All of these developments can significantly affect urban employment, although this tends to be sector specific. The consequent result is that concentration of economic activity is likely to increase, due to which the potential for agglomeration economies is stimulated. This seems to be true for both urbanization as well as localization economies. It should be noted that this effect, especially for urbanization economies, likely does depend on the type of infrastructure. Urban road infrastructure connecting the city center to the urban fringe can in fact induce movements of residents away from the center of a city to its suburbs, which decreases population density and thus the urbanization agglomeration effect (Baum-Snow, 2007). For localization economies (employment), such a decrease in density is less probably, because displacement of firms and jobs to suburbs resulting from infrastructure investment is much less pronounced (Baum-Snow, 2013).

2.3 Research Question

The empirical results from the studies presented in the previous chapter show the gap in the literature this literature review has identified, and which the empirical study following it will aim to fill. For the European transport network, accessibility changes have been studied, and the impact of those changes on regional GDP changes and EU cohesion. From Jacobs-Crisioni and Koomen (2017), we also know there are important distinctions for this network between domestic and cross-border accessibility. While previous studies that did not make a distinction between the two types of accessibility showed overall positive effects on regional growth, Jacobs-Crisioni and Koomen showed it is in fact domestic accessibility enhancement which drives regional growth, without any significant impact brought about by cross-border accessibility. What is missing for a more complete evaluation of the European infrastructure network and transport policy are estimates of regional economic effects beyond GDP and population. Such factors can be Wider Economic Impacts such as employment and specialization. Peters' (2003) argumentation for the EU transport policy concerning cohesion versus urban and regional agglomeration effects has also not been tested empirically, to my knowledge. Urban economies in general have been lacking in previous research, including whether economic activity indeed clusters as a result of the construction of the network, as New Economic Geography predicts. If it does, we would observe an increase in urban density or size of economic activity and/or employment, spurring external agglomeration benefits from transport investment (Graham, 2007). Lastly, it is important to continue the distinction between domestic and cross-border accessibility as centered in Jacobs-Crisioni and Koomen (2017), in order to see where the possibilities lie for the European transport network to have an impact on regional economies. These observations have given rise to the following research question:

> *How has investing in the European infrastructure network, and the subsequent regional domestic and cross-border accessibility enhancement, affected localization economies - measured as employment density - in European NUTS-3 regions?*

According to the urban agglomeration literature, there are two main components of agglomeration economies which can play a role: urbanization and localization economies. Urbanization economies have already been addressed in previous research on population growth effects (e.g. Jacobs-Crisioni and Koomen, 2017; Batista e Silva et al, 2013). The empirical research which will aim to answer the proposed research question will therefore focus on localization economies. It is most commonly measured as employment size and composition. We will use regional employment data disaggregated to different sections in order to quantify the effect of European accessibility changes on regional employment density and specialization. This approach, following Chandra and Thompson (2000), allows us to study the more specific spatial allocation of different economic activities.

The main research question can be split into several sub-questions. Answering each will provide a more comprehensive understanding of the mechanisms at play. The following sub-questions will be answered:

1. *Do domestic and cross-border accessibility levels have different impacts on regional employment density levels in Europe?*
2. *Do impacts differ spatially between core, intermediate and peripheral regions?*
3. *Do we observe the u-shaped relation between accessibility and employment?*

4. *How are the identified effects different between economic sectors?*
5. *How do domestic and cross-border accessibility levels affect regional specialization levels in Europe?*
6. *Can we identify spillover or backwash effects between regions?*

The empirical model will be partly based on the models used by Jacobs-Crisioni and Koomen (2017) and Crescenzi and Rodriguez-Pose (2008). They, too, examine the regional impact of infrastructure and accessibility. Crescenzi and Rodríguez-Pose (2008) also take into account regional spillover effects, although their dependent variable is the growth rate of regional GDP per capita. The variable of interest for Jacobs-Crisioni and Koomen is population growth, which is interesting on its own but also as a proxy for regional economic growth. A difference between the present paper and Crescenzi and Rodríguez-Pose (2008) is that they use regional data on a rather large scale (NUTS 1 and 2). We will use data on a smaller scale (NUTS-3), which is necessary in order to identify effects on a scale as small as single urban regions. Crescenzi and Rodriguez-Pose use European motorways (length in km) as infrastructure variable. We will be using accessibility data based on travel time over the infrastructure network and population (as in Jacobs-Crisioni and Koomen, 2017), which better reflects connectivity of a region and the exact added value of upgrades to the network. Following Chandra and Thompson (2000), we will add control variables to explain trends in the relative importance of different economic sectors over time. Our model is a fixed-effects panel data model, as used by Crescenzi and Rodriguez-Pose (2008), Jacobs-Crisioni and Koomen (2017) and Chandra and Thompson (2000).

3. Methodology and Data

Following the framework presented in the previous chapter, this section will present the empirical model used to test the hypotheses. The empirical study will aim to establish a causal relationship between accessibility (domestic and cross-border) and urban employment density growth, in order to judge the network's impact on the potential for agglomeration in European cities. Other endogenous and external factors will be incorporated, in order to strengthen the claim of causality.

3.1. Regional Accessibility

At the basis of the empirical analysis is the use of an adequate spatial measurement of regional accessibility in relation to domestic and cross-border locations. We will make use of the accessibility values computed by Jacobs-Crisioni and Koomen (2017). The data are based on infrastructure network connections and population data and split into base and highway accessibility. Base accessibility refers to the travel times over a slow base network, whereas highway accessibility refers to the additional interaction opportunities offered by Europe's highways. The measurement is an adaption of the gravity model, resulting in a measure for potential accessibility:

$$A_{i,t} = \sum_{i \neq j}^{n} P_{j,t} (M_{ij,t})^{\gamma} \qquad \text{(i)}$$

Accessibility *A* for origin municipality *i* is determined by the size of all destination municipalities *j*, and distance-decayed travel-times in minutes *M* from *i* to *j* over the network. That means *A* is solely a measure for external accessibility, excluding internal interaction potential within each municipality.

Jacobs-Crisioni and Koomen explain external accessibility is sufficient for their study of transport network effects on population growth, because the framework builds on the theory of access to outside markets. This same argument applies to the present study on employment effects. Since we are not looking at agglomeration effects directly, but at the potential for their occurrence through sectoral employment growth induced by enhanced market access, the accessibility measure supplied by Jacobs-Crisioni and Koomen suffices. The power distance decay of $\gamma = -2$ is maintained. See Jacobs-Crisioni and Koomen for further specifications of the accessibility index.

One change we have made to the original data is an aggregation from municipal level to NUTS-3 regional level. To illustrate: the Netherlands as a country is measured at NUTS-1 level, the province South-Holland corresponds to NUTS-2, and NUTS-3 refers to the COROP regions, one of which is for instance the agglomeration of The Hague. This aggregation to NUTS-3 was necessary because employment data split to sectors is not available at the municipality level. Aggregation was done using the GIS software ArcMap. For each NUTS-3 region, the corresponding municipalities were identified. Municipality accessibility averages where then computed to find the domestic and cross-border accessibility values for the NUTS-3 regions. Averages were chosen because summation would not accurately reflect accessibility, and it would present the problem of NUTS-3 regions enclosing different numbers of municipalities. This aggregation approach did come with some drawbacks. The first is that averages are not weighted. The second is that aggregation inevitably introduces self-accessibility, something which was intentionally excluded in the original values computed by Jacobs-Crisioni and Koomen. However, despite these alterations, we observe a high correlation between the original data and the new data when comparing the datasets on a grid-level. As such, the new data is sufficiently accurate.

We have chosen to use linear interpolation to convert the data from one observation per decade to one observation per year, for each NUTS-3 region. Linear extrapolation was used for the years beyond 2011. Examining the original data revealed there was already a trend very similar to a linear one between 1971 and 2011. Assuming the accessibility growth to be linear is therefore in line with the observed growth. Moreover, it is suitable for the slow and continuing pace in which infrastructure is upgraded and constructed.

3.2. Employment

Employment is measured as employment density, in order to deal with the Modifiable Areal Unit Problem (MAUP). Employment density is also the best representation of localization economies, in which closeness of economic activity plays an important role. The resulting measure gives us total employment (number of people) per $100km^2$. The dataset also provides us with information on sectoral employment. The following sectors are identified: agriculture, construction, industry and services, the latter of which is a rather broad group including trade and transport activities as well as public and private services, such as financial services. The sectors included are based on the International Standard Industrial Classification (ISIC) level 4. We also construct a specialization index, represented by the Hirschman-Herfindahl Index (HHI). This index, which is most often used in studies on market concentration, can also be used to express economic specialization and changes over time (Palan, 2010). The index measures absolute specialization, for it does not compare regions to each other. Because of its nature, the index does not tell us which region is specialized in which

sector. In order to gain some intuitive understanding on this matter, we will interpret the results for specialization together with the results on the shares of different sectors.
The Hirschman-Herfindahl Index is expressed as follows:

$$HHI_{KH} = \sqrt{\sum_{i=1}^{I} b_i^2} \ , \qquad \text{(ii)}$$

in which b_i is the percentage share of industry i of total employment in a region. *HHI* will take the maximum value of 100 when a region is fully specialized in one sector. It will take a minimum value of 50 when there is no specialization and all industries have an equal share in employment.

3.3. Model

To test the effect of domestic and cross-border accessibility on regional employment sizes and specialization, we use a panel data approach for NUTS-3 regions *i* over time *t* (from 2000-2016). The use of a panel data model allows for measuring within-unit effects, thereby controlling for time-invariant regional heterogeneity of factors such as economic structure, labour markets, culture and political decision-making. In principle, we can assume that such factors are present across EU regions. When they are correlated to any independent variables used in the model, this can give rise to endogeneity issues of omitted variable bias. Specifically, correlation of omitted region-specific factors to accessibility growth would pose a problem. Such a correlation likely exists, as Gibbons et al (2012) explain, for instance because regions with productive or location advantages received better infrastructure connections and enjoyed higher economic growth. Controlling for such factors implicitly and minimizing the bias requires the application of a fixed-effects method. We test the choice for this model by means of a Hausman test that compares fixed effects results to the alternative of random effects. The test shows the appropriateness of fixed effects. Unlike Jacobs-Crisioni and Koomen (2017), we do not include time fixed effects, because such effects would introduce too high correlation due to the way in which the accessibility values have been linearly constructed.

We fit the following basic regression equation:

$$ln(E_{i,t}) = \beta_0 + \alpha_i + \beta_1 ln(A^{dom})_{it} + \beta_2 ln(A^{for})_{it} + \varepsilon_{it.} \qquad \text{(1.a.)}$$

$E_{i,t}$ measures the level of employment density in region *i* during year *t*, either over all sectors or for single sectors. When looking at specialization, *E* represents the specialization index. A^{dom} gives us the accessibility level of a region when only considering domestic destinations. A^{for} only takes into account cross-border destinations. α_i is a region-specific fixed effect, invariant over time *t*. All models we run correct for heteroskedasticity robust standard errors, because plots of the data reveal the presence of heteroskedasticity, even after taking the natural logarithm of the variables. Expressing variables in natural logarithm also dealt with some outliers in the data.

When $E_{i,t}$ represents sectoral employment, it is important to consider the possibility that the variable shows a trend, representing the change in modern-day economies away from traditional sectors such as agriculture and heavy industry towards high-tech industries and, most of all, the services sector. In the descriptive statistics section, we will study this possibility more closely. When there is indeed a trend in the data, we want to reflect this in the model. Then, knowing there is a general trend in the relative role of different industries, we can still examine how this differs across different regions, based on i.a. their level of accessibility, which is the goal of our study. Not controlling for such a trend could result in wrongly establishing a causal relationship between a trend in growing accessibility and, e.g. a trend in the growth of the services sector (thus finding a spurious correlation). Chandra and Thompson (2000) stress this in their study on infrastructure and economic activity for the United States. They tackle the issue by controlling for economic trends reflecting factors such as consumer and industrial demand for an industry's products, changes in labour productivity in an industry, and the phase of the national business cycle. We, too, will include such control variables in an extended version of our basic regression. The choice for these variables was additionally based on the works by Gibbons et al (2012), Crescenzi & Rodriguez-Pose (2012), Carbo et al (2019) and Wetwitoo & Kato (2017). The availability of data at the regional level means a selection of control variables used by the works mentioned is used. The control variables include the rate of unemployment, gross fixed capital formation and average worker compensation. The latter two are industry-specific when we study industries separately, so they reflect industrial trends. Gross fixed capital investment, for instance, is closely related to industrial labour productivity. Capital investment also reflects automation trends, as does unemployment. Worker compensation in an industry reflects not only the demand for and supply of specific labour, but also industrial turnover, profit and the relative importance of the industry in the economy.

We also introduce an interaction effect, interacting the accessibility variables with a categorical variable U_{it} identifying urban typology for each region. This typology was taken from the European Union's Eurostat. It divides NUTS-3 regions into the categories of urban, intermediate, rural (close to a city) and rural (remote). The division was constructed as follows:

1. It creates clusters of urban grid cells with a minimum population density of 300 inhabitants per km² and a minimum population of 5 000. All the cells outside these urban clusters are considered as rural.
2. It groups NUTS 3 regions of less than 500 km² with one or more of its neighbours solely for classification purposes, i.e. all the NUTS 3 regions in a grouping are classified in the same way.
3. It classifies NUTS 3 regions based on the share of population in rural grid cells. More than 50 % of the total population in rural grid cells = predominantly rural, between 20 % and 50 % in rural grid cells = intermediate and less than 20 % = predominantly urban.

The classification also takes into account the presence of a city within a region. All regions containing a city with a population over 200.000 are classified at minimum as intermediate, and regions with cities of over 500.000 inhabitants are classified as urban. Lastly, rural regions are separated into those close to a city and those which are considered remote. We use this classification to represent the core-periphery distinction across regions as proposed by Krugman. The EU's classification is closely related to this model. Krugman based his interpretation of core regions on economic clustering and resulting market size, which causes cities to form. Periphery regions, on the other hand, are those regions for which we do not observe such a strong clustering effect. A classification based on density as well as size, therefore, accurately reflects this distinction made between region types. Throughout the remainder of the paper, whenever we refer to urban regions, these are the core regions as visualized in the core-periphery model.

Because we use a fixed effects model, which does not allow for time-invariant factors such as region type as individual regressors, the effect of region type is not estimated separately. Our main interest is not in the individual effect of region type, so we go ahead and estimate the fixed effects model as specified in the following equation, with interaction effects and the vector of control variables X_{it}:

$$ln(E_{i,t}) = \beta_0 + \alpha_i + \beta_1 ln(A^{dom})_{it} + \beta_2 ln(A^{for})_{it} + \beta_3 ln(A^{dom})_{it} U_{it} + \beta_4 ln(A^{for})_{it} U_{it} + \beta_5 X_{it} + \varepsilon_{it.} \quad (1.b.)$$

Since U_{it} does not enter as a separate variable, we minimize concerns of errors in the model and bias due to correlation between accessibility levels and urban classification. Even though accessibility was not constructed in such a way that it directly incorporates the population size of region *i* by Jacobs-Crisioni and Koomen (2017), it does effectively depend on population size, because larger (urban) regions just tend to be better connected. Also, they tend to be surrounded by regions *j* of larger population size, and this does directly enter in the equation representing accessibility (Jacobs-Crisioni and Koomen, 2017, p. 81). Entering both variables as independent variables would cause some multicollinearity in the model. However, we are allowed to interact two such correlated variables, just as it would be no problem to enter a squared variable (effectively interacting a variable with itself). Running the model and checking the Variance Inflation Factor (VIF) confirmed that problems of multicollinearity are not present.

In a third model, we also study employment density, but we leave out the control variables and interaction effects, and instead we enter the variables for domestic and cross-border accessibility as squared values. This allows us to test the claims made regarding diminishing returns to accessibility and a u-shaped relation, which we discussed in chapter two. We center the variables themselves and their squares. This results in the following model:

$$ln(E_{i,t}) = \beta_0 + \alpha_i + \beta_1 ln(A^{dom})_{it} + \beta_2 ln(A^{for})_{it} + \beta_3 ln(A^{dom})_{it} * ln(A^{dom})_{it} + \beta_4 ln(A^{for})_{it} * ln(A^{for})_{it} + \varepsilon_{it.} \quad (1.c.)$$

The main goal of this study is to identify causal effects. Causality is dependent on various factors, being: i) no perfect multicollinearity, ii) independent and identically distributed (i.i.d.) random variables are used, iii) no simultaneous causality, iv) no omitted variables. The first factor is not a concern, as the test for Variance Inflation Factor (VIF) shows. The second factor is also met, as our sample size is large and a unit root test showed our data to be stationary. As previous literature explains (Jacobs-Crisioni and Koomen, 2017; Duranton and Turner, 2012; Percoco, 2015), the third factor is of major concern in an analysis such as this one. The geography of infrastructure networks is possibly endogenous with respect to regional development, so that accessibility values might be biased. This is due to the fact that decisions concerning infrastructure improvements can be expected to be driven by actual development or growth potential of regions. High employment signals large economic activity, which drives the demand for transportation and migration, so that we can expect those regions which grow the most or are expected to do so are allocated the largest efficiency upgrades in their infrastructure network. As a result, in our empirical analysis, both reverse causality and omitted variables may bias the estimation. However, as Gibbons et al (2012) note, there are often long delays between the commissioning of new infrastructure links and the actual opening. This weakens the relation between regional growth trends and the decision of project locations. On the other hand, it is not just present growth rates which determine infrastructure investment decisions, but also projected rates of growth and demand for transportation. If projections are generally accurate, we may at least expect some relation between the two.

The use of a fixed-effects panel data model deals with most concerns of omitted variable bias. However, even though it also partly addresses simultaneous causality, this might still be present, namely when employment changes affect accessibility changes within a region over time. Previous works deal with this issue by using historical variables as an instrument for accessibility to extract exogenous variation from this variable. Baum Snow (2007) and Duranton et al (2014) use the 1947 U.S. highway plans as an instrument for the modern-day highway network. Percoco (2015) uses the road network from the Roman Empire for studying Italy. The same network is used by Garcia-Lopez (2018) for a Europe-wide study. An alternative to using instruments is the inclusion of past values for regressors (Jacobs-Crisioni and Koomen, 2017; Crescenzi and Rodriguez-Pose, 2012). We will apply the use of lags in the regressors and use a one-year lag, similar to Gibbons et al (2012).

In order to further address endogeneity concerns, we will apply a two-stage least squares analysis in the chapter on robustness, using an instrumental variable which reflects historic accessibility over old European trade routes. The instrument is used for the domestic accessibility variable only. This choice was motivated by the assumption that endogeneity is mostly a problem for domestic accessibility, because (political) choices regarding the construction and upgrading of domestic routes likely depend on population and employment exerting pressure on transportation demand. We argue that this is less of a problem for cross-border accessibility, because it mostly depends on distance to the national border, due to the way in which the values are constructed. There is of course also a population component in cross-border accessibility, and connections across national borders are likely influenced by the population and employment size of the regions being connected. However, as we can see in figure 3 below, the distance to the border component dominates the value taken on by cross-border accessibility. This reduces the concern for endogeneity of the cross-border accessibility variable.

The GIS data for the historical network was provided by Ciolek (1999) and can be found at www.ciolek.com/OWTRAD/DATA/oddda.html. It includes Europe's chief trade routes during the end of the Middle Ages (1300-1500 C.E.). It is thus a similar measure as used by Percoco and Garcia-Lopez, in that it reflects historical infrastructure and accessibility. Our identifying assumption is that historical accessibility at least partly determines accessibility of European regions today, and that it does not directly affect employment density changes today. This is a reasonable assumption to make. The network is old enough to not affect employment changes today. At the same time, historical accessibility is very likely to have determined accessibility of places today, through the path-dependency of locations of towns, their accessibility over main trade routes and their growth of population and economic activities. The instrument is rather crude, as it is expressed as the number of links of the historical network running through each region. However, it is suitable: the F-test from the first stage regression shows it to be sufficiently related to present-day accessibility (F-value = 11), and an additional regression between the historic network variable and employment density shows no direct significant relation between the two.

In order to measure spillover effects between regions, we fit a spatial autoregressive model after running the basic model. Specifically, a spatial cross-regressive model will allow us to introduce the accessibility values of surrounding regions as a regressor, in addition to the own accessibility of any region i. This use of spatially lagged variables is also used by Crescenzi and Rodriguez-pose. It not only provides us with insight on the importance of neighboring regions, but it also minimizes their effect on the residuals. It therefore leads to a further improvement of the specification of the model if neighboring regions indeed affect others. We fit a spatial cross-regressive model as follows:

$$ln(E_{i,t}) = \beta_0 + \alpha_i + \beta_1 ln(A^{dom})_{it} + \beta_2 ln(A^{dom})_{it} U_{it} + \beta_3 Wln(A^{for})_{jt} + \beta_4 Wln(A^{for})_{jt} U_{it} + \beta_5 Wln(A^{dom})_{jt} + \beta_6 Wln(A^{dom})_{jt} U_{it} + \beta_7 X_{it} + \varepsilon_{it}.. \quad (2)$$

The difference between this equation and the previous one is that we include spatially-weighted accessibility values of surrounding regions j for each region i. We use a row-standardized inverse-distance matrix to determine the weights W. Regions whose centers lie more than 75 km from the center of region i (measured in Euclidean distance) are given a value of zero, meaning they are not considered as neighbors which are of any influence on region i. The band of 75 km was chosen because we expect regions to only influence each other when they are located in close proximity. Note that the cross-border accessibility of region i is missing from the equation. This was done because the correlation between A^{for}_{it} *and* A^{for}_{jt} was so high that they are almost perfectly collinear. Moran's I was close to 90. Excluding foreign accessibility in region i from the regression is not seen to be a problem, because we estimate its effect separately before we test this model. Also, for this specific model, our main interest is in regional spillovers, so we want to property estimate the effects of neighboring accessibility values. We do include domestic accessibility of region i for completion. The resulting model can simply be estimated using OLS or, in our case, fixed-effect panel data regression.

3.4. Data

The accessibility data were provided by Jacobs-Crisioni and Koomen from their 2017 study. The employment data was taken from the OECD. Due to the fact that the data only span from 2000 to 2016, making use of this dataset severely shortened the time period under consideration. However, other data at the regional level is unavailable. The data for the control variables was taken from the OECD en Eurostat. The dataset spans the same ten Western European countries covered by Jacobs-Crisioni and Koomen (see appendix). After transformation of the accessibility data, we analyze all data at the NUTS-3 regional level, following the official European Commission classification of EU regions. The regional urban and rural typology was also taken from the EC.

3.5. Descriptive Statistics

Below, the main variables used in this study are summarized, split to region types (Table 2). We take the average values over all years, first. The accessibility values do not necessarily have an interpretation on their own, other than that higher values reflect higher accessibility. We see that mean domestic accessibility (IN) is significantly higher in urban regions when looking over all years. Somewhat surprisingly, cross-border accessibility (EX) is also highest in urban regions, despite the fact that it are often rural regions which are located closer to national borders. The gap to other regions types, however, is not as large as for domestic accessibility. Employment density is also much higher in urban regions compared to non-urban regions.

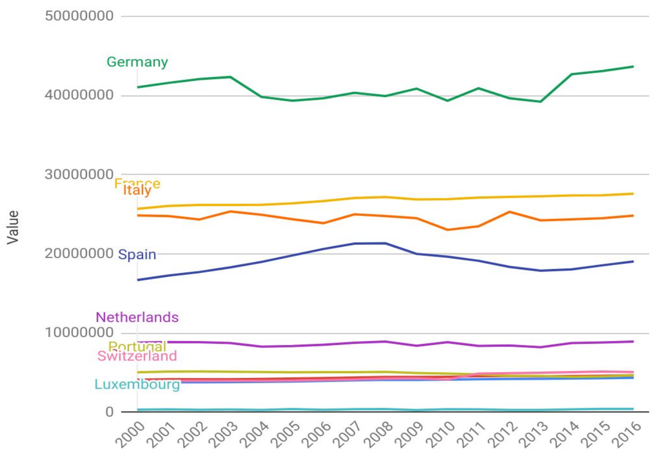
Next, we would like to have an idea of the trends over time. This is not just interesting from the viewpoint of having a better understanding of how our variables behaved since the year 2000. As we mentioned in section 3.3., studying trends also allows us to know how our study and our results might be influenced by such trends, especially when looking at employment and sectoral changes.

Table 2. Descriptive Statistics

Mean Values per Region Type	IN	EX	Employment Density	Share of Construction	Share of Agriculture	Share of Industry	Share of Services and Transport
Urban	12696,62	1803,53	669,14	6,08	1,86	17,34	74,72
Intermediate	4720,56	1274,45	157,25	7,18	3,85	19,85	69,13
Rural, close to a city	3429,79	1049,42	60,43	7,86	6,28	20,62	65,25
Rural, remote	1642,86	513,71	27,40	8,36	12,05	15,86	63,73
All Regions	6303,37	1303,05	259,81	7,13	4,56	19,01	69,30

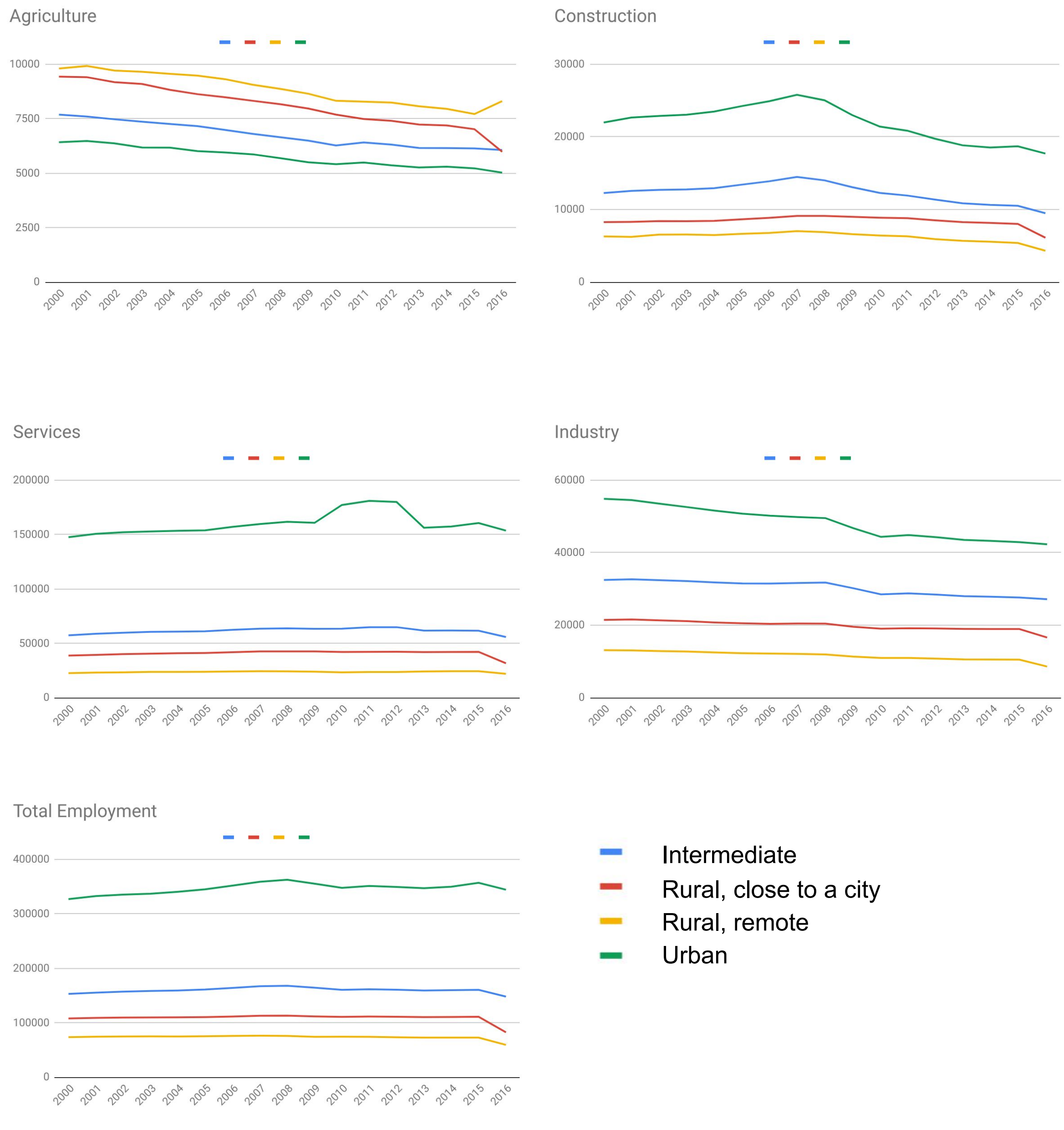
The maps in the following section cover regional accessibility changes over time. For employment, we present graphs in this section (see below) that show employment levels for each year between 2000 and 2016. They cover total employment as well as the employment share of each sector. Figure 1 shows us national employment values for all sectors. In figure 2, we see the employment data split into region types as well as into economic sectors.[1] Remarkably, the trends for each sector are rather similar across region types. Only urban regions tend to sometimes diverge. For the present study, the most interesting development to explain in the empirical analysis will be the growing employment pool in urban regions, while employment in rural regions does not exhibit this growth. In addition, while total employment only increased marginally, with the highest increases in urban regions, we see the data reflect some of the modern-day trend of economies switching from traditional sectors such as agriculture to service-related sectors. While this pattern in the data is not very strong, it is present. It can influence our results and show a relation between accessibility and employment when there is in fact none. As such, as explained in section 3.3., we aim to detrend the data and eliminate any spurious relation by adding controls which explain the economic trends in sector sizes over time.

Figure 1. National Total Employment



[1] Note the vertical axes have different scaling for each graph. This was done for clarity in the image.

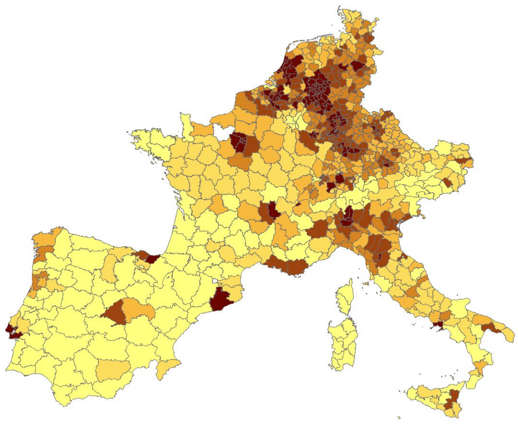
Figure 2. Regional Employment Trends



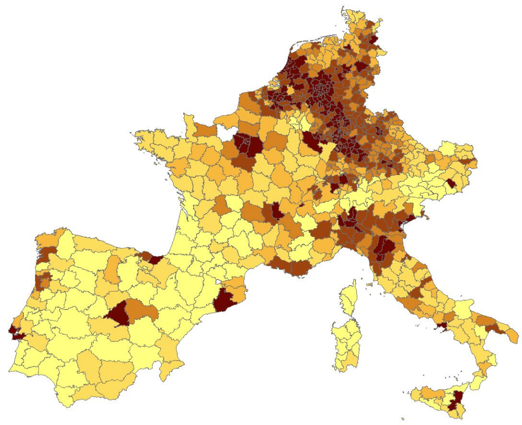
3.6. Geographic Representation

In the figure below, we see the maps of accessibility and employment density values. Accessibility is shown for 2001 and 2011, to illustrate the changes across space that have taken place over this decade. Due to the way accessibility values have been interpolated, they would show a linear growth when they are put into a graph. Accessibility values, both domestic and cross-border, have generally grown in all region types. The strongest growth is concentrated in and around regions which has the highest accessibility levels to start with. Cross-border accessibility on the other hand has, logically, experienced the strongest growth in regions close to national borders. Cross-border accessibility is not homogenous across all border regions. Regions in the North-West, located in the Netherlands, Germany, Belgium, Switzerland and Austria, clearly show much higher accessibility levels and growth compared to other border regions, such as those located on the border between France and Spain or Spain and Portugal. It is likely that better cross-border infrastructure connections as well as more density populated regions play a role in this distinction.

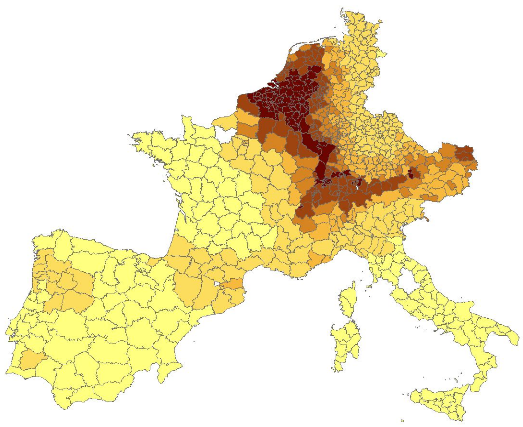
Figure 3. Accessibility Maps



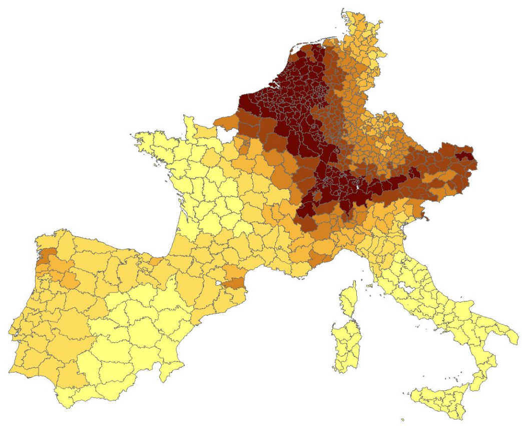
Domestic Accessibility (2001)



Domestic Accessibility (2011)



Cross-border Accessibility (2001)



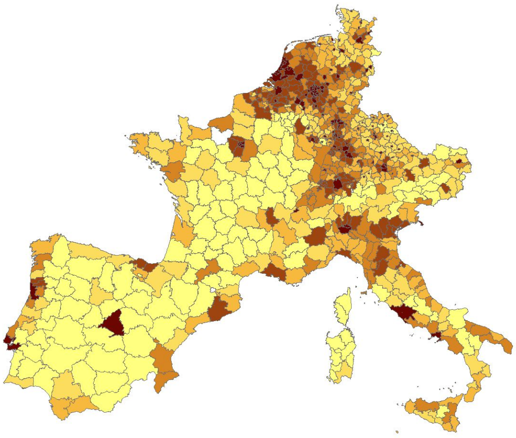
Cross-border Accessibility (2011)

High - Low

Accessibility

The next image represents employment density in 2011, to show the regional differences. Those differences are generally the same over time, and are not specific to the year 2011. The image confirms what we already saw in the descriptive statistics table: employment density is highest in urban and intermediate regions, and spiking in metropolitan (capital) regions.

Figure 4. Employment Map



Employment Density (2011)

High - Low
Employment Density

4. Empirical Results

This section presents the results of the regression analyses. The first sub-section is dedicated to the fixed-effects panel data analysis and spatial cross-regression analysis needed to answer our research questions. The second section then builds on these results by testing their robustness against various specifications.

4.1. Regression Results

We focus our attention on the results from model 1.b. (Table 3), which corresponds to equation (1.b.) in chapter 3.3. This model builds on model 1.a. by incorporating control variables and interactions effects, which significantly improves the explanatory power of the model. The adjusted R^2 goes from 0.139 up to 0.607, indicating model 1.b. explains 60% of the variation in employment density across space and time. The additions of controls and interactions effects show us that the impact of domestic and cross-border accessibility significantly depends on the region type. While model 1.a. shows cross-border accessibility not to have a significant impact on employment density for all regions combined, model 1.b. tells us that the effects is positive for urban regions, and negative for rural (remote) regions. The coefficient for cross-border accessibility in urban regions is 0.0445, and it is significant at the 99% confidence level. Because our regression equation is log-log, this means a 1% increase in cross-border accessibility is associated with 0.0445% increase in the total employment level: a small effect, but this reflects the modest increases in regional employment we saw in figure 2. The coefficient for domestic accessibility it significant at the sufficient confidence level of 95%, and it is 0.0560.

Table 3. Employment Density (Total)

VARIABLES	Model 1.a.	Model 1.b.	Model 1.c.
Domestic Accessibility	0.179***	0.0560**	
(main effect, effect for urban in model 1.b.)	(0.0212)	(0.0236)	
Cross-border Accessibility	0.00318	0.0445***	
(main effect, effect for urban in model 1.b.)	(0.00962)	(0.0111)	
Intermediate*Domestic Accessibility		0.0434	
		(0.0349)	
Rural close to a city*Domestic Accessibility		0.0627	
		(0.0545)	
Rural remote*Domestic Accessibility		0.0776*	
		(0.0438)	
Intermediate*Cross-border Accessibility		-0.0221	
		(0.0175)	
Rural close to a city*Cross-border Accessibility		-0.0535*	
		(0.0300)	
Rural remote*Cross-border Accessibility		-0.0914***	
		(0.0301)	
Domestic Accessibility (centered)			0.113***
			(0.0250)
Cross-border Accessibility (centered)			0.0623***
			(0.0156)
Domestic Accessibility (centered)_sq			0.0271***
			(0.00847)
Cross-border Accessibility (centered)_sq			0.00923***
			(0.00201)
R-squared	0.139	0.607	0.193
Region FE	YES	YES	YES
Controls	NO	YES	NO
Robust SE	YES	YES	YES
Lagged Values	YES (1 year)	YES (1 year)	NO

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Intermediate regions do not differ significantly from urban regions in the way they translate accessibility into employment. Rural regions, on the other hand, do differ strongly. For cross-border accessibility, there is a negative effect for rural regions at the margin, with stronger effects observed for remote rural regions. This becomes apparent once we combine the coefficient for the main effect (0.0445) with the coefficient for the interaction term (-0.0910), which results in an overall effect of cross-border accessibility on employment in remote rural regions of size -0.0465. This is an interesting finding, because it would be in line with Puga's (2008) argument that opening vulnerable, lagging regions to foreign competitive forces could have negative effects on those regions. This initial result hints at an anti-cohesion effect of European cross-border accessibility improvements. After Spiekermann and Wegener's (1996) finding that urban regions were favored in terms of receiving accessibility improvements from investing in the European transport network, the present results add to this the suggestion that equally large improvements in cross-border accessibility are only positive for urban regions, and negative for rural areas. There is thus a strengthening of already dominant agglomerations. Following Peters' argument on economic efficiency due to clustering (Peters, 2003), the results would support the claim that efficiency was indeed increased, at the expense of employment in rural regions.

The results for domestic accessibility do hint at a more pro-cohesion effect. Domestic accessibility has a positive effect on all region types. Because the interactions terms are positive, the effects are higher as we move from urban regions towards rural regions. This interpretation should be taken with caution though, because of the low or non-significance of the interaction terms. Only at the 90% confidence interval are remote rural regions experiencing significantly higher effects from domestic accessibility increases compared to urban regions. As such, remote rural regions would benefit from improvements in domestic accessibility, while improving cross-border accessibility only hurts their employment. In all region types, the effect of domestic accessibility is larger than the effect of cross-border accessibility on employment growth.

Interestingly, the results from model 1.c. in the table above somewhat contradict previous claims made regarding the diminishing effects of infrastructure improvements in Europe. The model, with squared accessibility values, was included to see if there is any evidence for non-linear relations between accessibility and employment. The regressors are centered to make interpretation more intuitive and to minimize correlation between the original term and the squared term. All coefficients are positive and significant at the 99% confidence level. The results suggest increasing effects of accessibility growth as accessibility is higher. One possible explanation for this is that there are increasing returns to accessibility, regardless of region type. A more likely explanation, though, is that urban regions, which are generally better accessible, are better able to take advantage from accessibility increases. They are, following Banister and Berechman's (2001) reasoning, better equipped in terms of their economic, investment and political climate to transform accessibility enhancements into the establishments of firms and growth of employment. We should be cautious in interpreting the results from model 1.c. as them showing that European infrastructure is still in the upward-sloping part of the u-curve described in chapter 2 for the core-periphery model. Along with this goes being cautious about claiming infrastructure improvement would still be a centripetal agglomeration (clustering) force. The explanation regarding urban regions and their potential to benefit from accessibility increases illustrates this, and as we will see in the following paragraph, increasing returns to accessibility are certainly not true for all sectors.

Next, we want to extract the results for different economic sectors. This is represented in the table below (Table 4). The regressions are performed for the natural logarithm of employment density for each sector. Again, we see that the effects become rather divergent when separating them. This is true for the distinction between economic sectors as well as between urban, intermediate and rural regions. The effects of domestic and cross-border accessibility are positive in urban regions for the services, trade and transport sector (column 4). They are the same in other region types for domestic accessibility. In remote rural regions, the effect of cross-border accessibility on services employment is somewhat lower than in urban regions, though still positive. For the other sectors, effects of domestic and cross-border accessibility growth in urban regions are negative. The fact that there is still an overall positive effect on total employment as we saw in the previous table is because effects are expressed in percentage growth, and the services sector is the largest sector in urban areas.

Table 4. Sectoral Employment Density

VARIABLES	Model 2.a. Construction Employment	Model 2.b. Agriculture Employment	Model 2.c. Industry Employment	Model 2.d. Services Employment
Domestic Accessibility	-0.321***	-0.328***	-0.491***	0.230***
(main effect, effect for urban)	(0.109)	(0.0896)	(0.0869)	(0.0488)
Cross-border Accessibility	-0.175***	-0.139***	-0.0879**	0.0894***
(main effect, effect for urban)	(0.0554)	(0.0437)	(0.0377)	(0.0304)
Intermediate*Domestic Accessibility	-0.0954	-0.125	0.223**	0.0359
	(0.145)	(0.124)	(0.107)	(0.0559)
Rural close to a city*Domestic Accessibility	0.519***	-0.376**	0.351**	0.0186
	(0.174)	(0.184)	(0.164)	(0.0663)
Rural remote*Domestic Accessibility	0.156	-0.0380	0.628***	0.0431
	(0.196)	(0.207)	(0.144)	(0.0700)
Intermediate*Cross-border Accessibility	0.0645	0.0641	0.0568	-0.00574
	(0.0712)	(0.0576)	(0.0459)	(0.0331)
Rural close to a city*Cross-border Accessibility	-0.184**	0.0524	0.0771	-0.0141
	(0.0930)	(0.0812)	(0.0743)	(0.0394)
Rural remote*Cross-border Accessibility	-0.0341	0.0677	-0.0913	-0.0693*
	(0.122)	(0.107)	(0.0718)	(0.0367)
R-squared	0.617	0.294	0.388	0.674
Region FE	YES	YES	YES	YES
Controls	YES	YES	YES	YES
Robust SE	YES	YES	YES	YES
Lagged Values	YES (1 year)	YES (1 year)	YES (1 year)	YES (1 year)

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

So what we observe is a drawback from construction, agriculture and industrial employment from urban areas, at least partly spurred by those areas becoming better accessible. The likely scenario is that, for those sectors, we are located on the downward-sloping part of the core-periphery u-curve. Accessibility across regions becomes so high that additional accessibility hardly matters, and any advantages for firms of being located in urban areas no longer weigh up against the costs of urban locations, such as land prices and high wages. As a result, it is more profitable for firms in certain sectors to locate outside urban centers. For the services sector, it is probable that not only the location advantages of urban regions still outweigh the costs, but also that better accessibility is still a centripetal force, drawing firms towards cities. For this sector, we would still be on the rising part of the u-curve of economic clustering. This is especially a likely scenario for corporate headquarters. For such businesses, urban advantages such as having ample opportunities for face-to-face contact is likely to play a role. As for the non-urban regions, when domestic accessibility increases, we see construction employment growing in rural regions close to a city, and industrial employment growing in remote rural regions. The data do not tell us whether the shrinkage in urban areas and the growth in rural areas is due to firms relocating (instead of the death and birth of firms). The agricultural sector is the only one showing shrinkage in all regions as a result of accessibility improvements. It is shrinking even faster in traditional agricultural regions, the rural areas close to a city, than in other areas. This result is in line with the findings in Chandra and Thompson (2000). The authors show agricultural activity not only being displaced but disappearing altogether, due to other sectors gaining in productivity as accessibility increases and transport costs fall.

In order to understand the workings of economic clustering and localization economies as spurred by accessibility growth, we must not only look at the absolute size of industries, as we have done in the previous paragraph, but we must also know their relative size, and how this changes as accessibility changes. We have constructed the Herfindahl-Hirschman Index (HHI) of economic specialization. It shows a growth over time, indicating more specialization, as Western European regions tend to abandon sectors such as agriculture and focus increasingly on services. What we want to know is if accessibility changes affect the different sectors in such a way that there is also an effect on economic specialization.

Table 5. Employment Specialization

VARIABLES	Model 3. HHI
Domestic Accessibility	10.10***
(main effect, effect for urban)	(1.680)
Cross-border Accessibility	2.316***
(main effect, effect for urban)	(0.869)
Intermediate*Domestic Accessibility	-0.178
	(1.808)
Rural close to a city*Domestic Accessibility	-1.099
	(2.375)
Rural remote*Domestic Accessibility	-3.449
	(2.840)
Intermediate*Cross-border Accessibility	-0.410
	(0.947)
Rural close to a city*Cross-border Accessibility	-0.489
	(1.182)
Rural remote*Cross-border Accessibility	-0.347
	(1.478)
R-squared	0.697
Region FE	YES
Controls	YES
Robust SE	YES
Lagged Values	YES (1 year)

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

As the results in Table 5 show, this is indeed the case. With the growth of the services sector and the shrinkage of other sectors in urban areas, they become increasingly specialized following improvements in domestic and cross-border accessibility. Especially domestic accessibility growth has a large effect on specialization. It also drives specialization at the margin in other region types, while cross-border accessibility mostly affects specialization in urban regions. Combined with the results presented in the previous two tables, these outcomes tell us that accessibility improvements indeed increase the potential for localization economies in urban areas. Not only does total employment density grow there, but cities also tend to become more specialized in their economic activity. This is something which, as Peters (2003) explains, enhances overall economic efficiency. What these results do not reveal is the effect of accessibility changes on relative specialization. The HHI only expresses specialization changes within one region. However, even when a region's specialization index decreases, for instance because the smallest sector grows and the largest sector shrinks, we might still say that this region is more specialized in the small sector compared to others, when that smallest sector decreases in other regions. The region is then relatively specialized and we say it has a comparative advantage in that sector. Something similar can be said to happen to rural regions which experience a growth in construction and industrial employment. Employment in these sectors decreases in urban regions as accessibility increases. Therefore, vis-à-vis urban regions, rural regions become relatively more specialized in construction and industrial activities following accessibility growth, although they might not have such an advantage compared to each other. A similar argument can be made for the services sector in urban regions.

We have seen that accessibility improvements in a certain region can have different effects on employment, depending on the type of region. Previous literature suggests that regional growth can, in addition to depending on its own accessibility, also be influenced by the accessibility of neighboring regions. The effects can either be positive (spillover effects) or negative (backwash effects), or again differ between region types. The former is a very plausible scenario. It can for instance happen when an urban region becomes better accessible, but firms prefer to locate in cheaper surrounding regions, where they can still enjoy the proximity of the high-accessibility urban market. A reversed scenario is also possible, in which hinterlands become better accessible but locating in urban regions is preferred, because it is now easier to supply the markets of hinterland regions without having a physical presence there. Previous works show that a negative backwash effect of urban regions on hinterland regions is in fact the most commonly found one. Regions whose neighbors become better accessible often lose out in terms of firm presence and employment.

Examining the empirical results in the table below (Table 6), we find that intermediate regions whose neighbors experience growing domestic accessibility are significantly less able to profit from this than urban regions. Urban regions profit most from neighbors gaining accessibility, whether it be domestic or cross-border. Once again, we see rural regions are also much less able to benefit and experience employment growth. Rural regions, especially remote ones, actually lose employment when neighbors gain domestic accessibility. For cross-border accessibility, the marginal effect is not significant. So there is no negative effect, but also no employment gains to be realized when neighbors become increasingly accessible across borders. In Table 3, we saw that remote rural regions lose employment when their own cross-border accessibility increases. As such, increasing cross-border accessibility as done within the EU policy framework in order to aid lagging regions would seem to have the opposite effect. If anything, there is support for a backwash effect going from urban regions towards non-urban regions, instead of a positive spillover effect.

Table 6. Spatial Cross-Regressive Model for Total Employment Density[2]

VARIABLES	Model 4.
Domestic Accessibility	0.0645***
(main effect, effect for urban)	(0.0245)
Neighboring Domestic Accessibility	0.0102***
(main effect, effect for urban)	(0.00322)
Neighboring Cross-border Accessibility	0.0317**
(main effect, effect for urban)	(0.0149)
Intermediate*Domestic Accessibility	0.0278
	(0.0302)
Rural close to a city*Domestic Accessibility	0.0269
	(0.0511)
Rural remote*Domestic Accessibility	0.0115
	(0.0674)
Intermediate*Neighboring Domestic Accessibility	-0.0189***
	(0.00522)
Rural close to a city*Neighboring Domestic Accessibility	-0.0113
	(0.0259)
Rural remote*Neighboring Domestic Accessibility	-0.0296
	(0.0443)
Intermediate*Neighboring Cross-border Accessibility	-0.00136
	(0.0167)
Rural close to a city*Neighboring Cross-border Accessibility	-0.0194
	(0.0219)
Rural remote*Neighboring Cross-border Accessibility	-0.0375*
	(0.0194)
R-squared	0.600
Region FE	YES
Robust SE	YES
Controls	YES
Lagged Values	YES (1 year)

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

[2] Cross-border accessibility of region i was left out of the regression due to the high correlation between this variable and the cross-border accessibility of surrounding regions. We can see this pattern in Figure 1 in the previous chapter. Moran's I (cross-regional correlation) is so high that including both variables would cloud the results. Domestic accessibility does not have this problem.

4.2. Robustness Controls

We instrument domestic accessibility with historic trade route data to extract exogenous effects. We use a two-stage least-squares approach. It is applied to our main model of interest: the model for total employment density. We report the results from the second stage here. The first stage showed our instrument to be a useful instrument. The F-value took a value of 11. In addition, regressing employment density on the instrument showed no significant relation between the two. We can therefore be sure that our instrument extracts exogenous variation from domestic accessibility, and that it does not affect our dependent variable directly.

Table 7. 2SLS Total Employment Density: Second Stage Results

VARIABLES	Model 5.
Domestic Accessibility	0.00650**
(main effect, effect for urban)	(0.00311)
Cross-border Accessibility	0.0442***
(main effect, effect for urban)	(0.0126)
Intermediate*Domestic Accessibility	0.00132
	(0.00408)
Rural close to a city*Domestic Accessibility	-0.00180
	(0.00347)
Rural remote*Domestic Accessibility	0.00849*
	(0.00496)
Intermediate*Cross-border Accessibility	-0.0335**
	(0.0151)
Rural close to a city*Cross-border Accessibility	-0.0451***
	(0.0134)
Rural remote*Cross-border Accessibility	-0.0496***
	(0.0138)
Region RE	YES
Robust SE	YES
Controls	YES
Instrument	# Historic Trade Route Links
Lagged Values	YES (1 year)

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The 2SLS analysis largely confirms our previous results. Domestic accessibility has a significant, positive effect on employment density. The effects are not very different between region types. For cross-border accessibility, we observe significant positive results for urban regions, similar to the outcome of our first regression. The interaction terms for the other regions types are, again, negative and significant. This indicates that non-urban regions, unlike urban regions, are not able to translate increases in cross-border accessibility into higher employment density.

5. Conclusion

This paper has studied the relation between regional accessibility and employment density, using historical data for ten West-European countries covering the years between 2000 and 2016. We exploit variation in domestic and cross-border accessibility levels over time and space to explain different levels of employment density in NUTS-3 regions, measuring total employment density as well as disaggregated to economic sectors. In addition, we study regional specialization differences, and we examine the existence of spillovers between regions. Our main goal was to answer the question of how accessibility enhancements in Europe have affected employment density (and its spatial allocation), which represents localization effects, so we can say something about the contribution of infrastructure investment to the workings of agglomeration economies. This can provide valuable information, to be used for instance when judging economic efficiency effects of transportation policies in Europe. Another important goal was to establish how the effects we find differ between core, intermediate and peripheral regions.

Making use of fixed-effects panel data regression analysis, we find empirical evidence for the conclusion that infrastructure and accessibility enhancements indeed affected the spatial allocation of employment across regions. The results show domestic accessibility to have a positive impact on total employment in all region types. Cross-border accessibility has a positive impact on employment in urban regions, but a negative impact in rural regions. An instrumental regression analysis, with historical trade route data instrumenting domestic accessibility, confirmed these results. Positive results are strongest for those regions in which accessibility and an increase in it are highest. For regions surrounding these high-accessibility regions, there tend to be negative spillover (backwash) effects as they lose employment. As such, it is not so much the net level of employment which changes in European regions over time, but the distribution across regions.

Additionally, we find accessibility to have very different effects on different economic sectors. European economies experience a general trend of declining activity in traditional sectors such as agriculture, and we find accessibility growth to have contributed to this. Our theoretical framework explained this phenomenon by observing that accessibility improvements likely increased the productivity of other sectors, drawing economic activity and employment away from sectors who are not able to benefit from such productivity growth. We indeed find that accessibility impacts only the services, transport and finance sector in a positive way. The relation with other sectors is negative. We do stress that the general trends in the growth of some sectors and the decline of others, combined with a long-term trend of increasing accessibility levels, make that we should be careful with firmly drawing such conclusions. Even so, knowing such trends are present in the data, the results are in line with theory and our predictions based on previous works. In order to be even more confident about the validity and causality in our results, we have added control variables which explain our observed trends, and which also function as proxies for time dummies. Complementary to finding that accessibility affects various sectors differently, we find that domestic and cross-border accessibility strongly drive specialization in urban regions, with the former also stimulating specialization in other region types.

In the introduction of this paper, we referred to Peters (2003) and Martin (1999) and the claim made by both authors that the goal of EU transportation policy - the enhancement of economic efficiency and global competitiveness - could only be reached by giving up the goal of regional cohesion. They argued that, instead of helping lagging regions grow, it would be more efficient to reinforce agglomeration economies in already high-performing regions. This would require designing policies, including those for infrastructure and regional accessibility, in such a way that they contribute to the growth of economic activity and specialization in core regions. Our empirical results suggest this has largely been achieved. Both domestic and cross-border accessibility have stimulated higher employment levels and more specialization in core (i.e. urban) regions. For peripheral regions, higher cross-border accessibility was related to smaller employment pools. The developments in regional accessibility in Western-Europe and the policies steering them, with a strong focus on cross-border accessibility, have therefore enhanced efficiency in the distribution of economic activity, at the cost of regional convergence.

With these conclusions, our main research question and derived sub-questions have been answered. We thereby hope to have filled a gap in the literature bridging regional infrastructure impacts on the one hand and agglomeration economies in employment pools on the other. The results can also be used to inform transportation policies, especially at a pan-European level. We have tried to tackle any limitations to the research design, especially those which could hinder our claim of causal relations. Even so, there are still limitations present, and gaps to be filled by future research. One suggestion is to deal with trends in the data by using first-differencing, something which would especially be valuable when using a longer time-span. Alternatively, the linear trend could be removed from the data altogether, leaving only the residuals left to estimate. The evidence for regional spillovers could be strengthened by showing whether it is robust to different matrix and weight formulations in the spatial cross-regression. For future research, it would be interesting to examine the relation between accessibility and specialization more closely. Our specialization index does not compare specialization of one region compared to others. It would be informative to see how comparative advantages across regions are influenced by accessibility changes. One could use a heterogeneity index such as the Krugman Specialization Index to do this (Palan, 2010). Splitting economic activity into more sub-sectors would also be of added value. We would like to conclude by stating that the topic of regional accessibility in Europe and its impact on the spatial distribution of economic indicators deserves further attention in general, due to its scientific, social and political significance, and the fact that there are still questions left unanswered.

Appendix

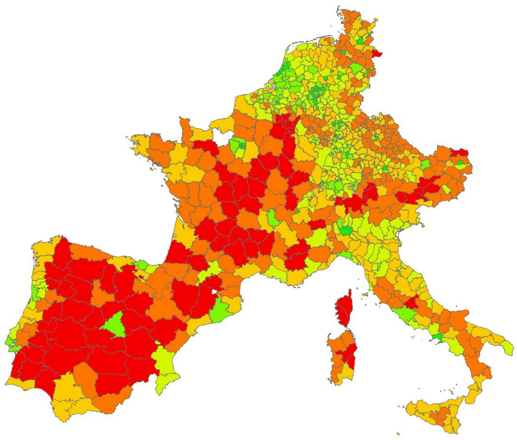
Countries

The Netherlands
Belgium
West-Germany
Luxembourg
France
Switzerland
Austria
Italy
Spain
Portugal

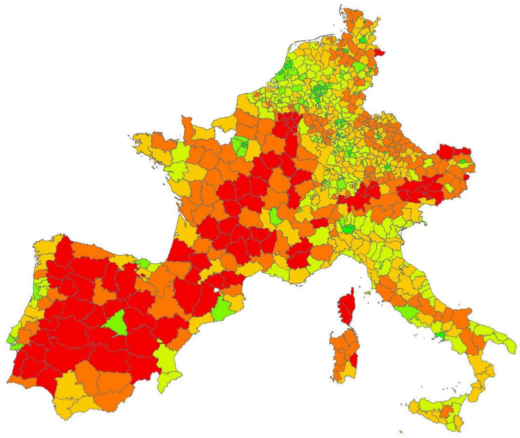
Data Sources

Variable	**Data Type**	**Source**
Domestic and cross-border accessibility	Continuous	Jacobs-Crisioni and Koomen (2017)
Employment	Continuous: number of people employed	OECD
Regional Typology	Categorical: 1 = Urban 2 = Intermediate 3 = Rural, Close to a City 4 = Rural, Remote	European Commission, Eurostat
The Rate of Unemployment	Percentage of the working force	OECD
Gross Fixed Capital Formation	Continuous: millions of euros	Eurostat
Average Worker Compensation	Continuous: millions of euros	Eurostat
Historical European Infrastructure Network	Converted from vector data to interval data, measuring the number of links per region	Ciolek (1999)

Geographical Representation of Fixed Effects from the Total Employment Model



Domestic Accessibility - Fixed Effects



Cross-border Accessibility - Fixed Effects

Red = Low / Negative
Green = High / Positive

References

Banister, D., Berechman, Y., 2001. Transport investment and the promotion of economic growth. J. Transp. Geogr. 9, 209–218.

Banister, D., Thurstain-Goodwin, M., 2011. Quantification of the non-transport benefits resulting from rail investment. J. Transp. Geogr.

Batista e Silva, F., Lavalle, C., Jacobs-Crisioni, C., Barranco, R., Zulian, G., Maes, J., Baranzelli, C., Perpiña, C., Vandecasteele, I., Ustaoglu, E., Barbosa, A., Mubareka, S., 2013. Direct and indirect land use impacts of the EU cohesion policy. assessment with the Land Use Modelling Platform. JRC Sci. Policy Reports.

Baum-Snow, N., 2013. Urban Transport Expansions, Employment Decentralization, and the Spatial Scope of Agglomeration Economies.

Baum-Snow, N., 2007. Did Highways Cause Suburbanization? Q. J. Econ. 122, 775–805.

Blanquart, C., Koning, M., 2017. The local economic impacts of high-speed railways: theories and facts. Eur. Transp. Res. Rev.

Blum, U., Heynes, K.E., Kalsson, C., 1997. Introduction to the Special Issue: The regional and urban effects of high-speed trains. Ann. Reg. Sci.

Boarnet, M.G., 1980. Spillovers and the Locational Effect of Public Infrastructure. J. Reg. Sci.

Bröcker, J., Schneekloth, N., 2005. European Transport Policy and Cohesion: An Assessment by CGE Analysis. 45th Congr. Eur. Reg. Sci. Assoc. "Land Use Water Manag. Sustain. Netw. Soc. 23-27 August 2005, Amsterdam, Netherlands, Eur. Reg. Sci. Assoc.

Carbo, J.M., Graham, D.J., Anupriya, Casas, D., Melo, P.C., 2019. Evaluating the causal economic impacts of transport investments: evidence from the Madrid–Barcelona high speed rail corridor. J. Appl. Stat.

Chandra, A., Thompson, E., 2000. Does public infrastructure affect economic activity? Evidence from the rural interstate highway system.

Chatman, D.G., Noland, R.B., 2011. Do Public Transport Improvements Increase Agglomeration Economies? A Review of Literature and an Agenda for Research. Transp. Rev.

Cheng, Y., Loo, B.P.., Vickerman, R., 2015. High-speed rail networks, economic integration and regional specialisation in China and Europe.
Ciolek, T. Matthew (ed.). 1999 - present. Georeferenced historical transport/travel/communication routes and nodes - Europe. OWTRAD Dromographic Digital Data Archives (ODDDA). Old World Trade Routes (OWTRAD) Project. Canberra: www.ciolek.com - Asia Pacific Research Online. www.ciolek.com/OWTRAD/DATA/oddda.html
Crescenzi, R., Rodríguez-Pose, A., 2008. Infrastructure endowment and investment as determinants of regional growth in the European Union. EIB Pap. 13, 62–101.
Duranton, G., Puga, D., 2003. Micro-Foundations of Urban Agglomeration Economies. Work. Pap. Ser.
Duranton, G., Turner, M.A., 2012. Urban Growth and Transportation. Rev. Econ. Stud. 79, 1407–1440.
Gerritse, M., Arribas-Bel, D., 2018. Concrete agglomeration benefits: do roads improve urban connections or just attract more people?
Gibbons, S., Lyytikäinen, T., Overman, H., Sanchis-Guarner, R., 2012. New Road Infrastructure: the Effects on Firms.
Graham, D.J., 2007. Agglomeration, Productivity and Transport Investment. J. Transp. Econ. Policy.
Graham, D.J., Melo, P.C., 2011. Assessment of Wider Economic Impacts of High-Speed Rail for Great Britain.
Gutiérrez, J., 2001. location, economic potential and daily accessibility: An analysis of the accessibility impact of the high-speed line Madrid – Barcelona – French border. J. Transp. Geogr.
Gutiérrez, J., Urbano, P., 1996. Accessibility in the European Union: the impact of the trans-European road network. J. Transp. Geogr. 4, 15–25.
Holl, A., 2006. A Review of the Firm-Level Role of Transport Infrastructure with Implications for Transport Project Evaluation. J. Plan. Lit.
Holl, A., 2004. Manufacturing location and impacts of road transport infrastructure: empirical evidence from Spain. Reg. Sci. Urban Econ. 34, 341–363.
Ibáñez, J.N., Rotoli, F., 2017. Measuring the Impact of the Trans-European Road Transport Network on the Accessibility of European Urban Agglomerations. Transp. Res. Rec. J. Transp. Res. Board 2605, 72–82.
Jacobs-Crisioni, C., Koomen, E., 2017. Population growth, accessibility spillovers and persistent borders: Historical growth in West-European municipalities. J. Transp. Geogr. 62, 80–91.
Johansson, B., Quigley, J.M., 2004. Agglomeration and networks in spatial economies. Pap. Reg. Sci.
Krugman, P., 1991. Increasing Returns and Economic Geography. Journal of Political Economy.
Lakshmanan, T.., 2011. The broader economic consequences of transport infrastructure investments. J. Transp. Geogr.
López, E., Gutiérrez, J., Gómez, G., 2008. Measuring Regional Cohesion Effects of Large-scale Transport Infrastructure Investments: An Accessibility Approach. Eur. Plan. Stud. 16, 277–301.
McCann, P., Shefer, D., 2004. Location, agglomeration and infrastructure, in: Fifty Years of Regional Science. Advances in Regional Science. Springer Berlin, Heidelberg, pp. 177–196.
Ottaviano, G.I.P., 2008. Infrastructure and economic geography: An overview of theory and evidence. EIB Pap. 13, 8–35.
Palan, N., 2010. Measurement of Specialization, The Choice of Indices, FIW Working Paper, No. 62, FIW - Research Centre International Economics, Vienna
Percoco, M., 2016. Highways, local economic structure and urban development. J. Econ. Geogr. 16, 1035–1054.
Peters, D., 2003. Cohesion, Polycentricity, Missing Links and Bottlenecks: Conflicting Spatial Storylines for Pan-European Transport Investments.
Pol, P.M.., 2003. The Economic Impact of the High-Speed Train on Urban Regions. 43rd Congr. Eur. Reg. Sci. Assoc. "Peripheries, Centres, Spat. Dev. New Eur. 27th - 30th August 2003, Jyväskylä,

Finl. Eur. Reg. Sci. Assoc.
Puga, D., 2008. Agglomeration and cross-border infrastructure. EIB Pap. 13, 102–124.
Puga, D., 2002. European Regional Policies in Light of Recent Location Theories. J. Econ. Geogr.
Rothengatter, W., 2005. Wider economic impacts of transport infrastructure investments: Relevant or negligible? Transp. Policy.
Spiekermann, K., Wegener, M., 2006. Accessibility and spatial development in Europe. Sci. Reg.
Spiekermann, K., Wegener, M., 1996. Trans-European Networks and Unequal Accessibility in Europe. Eur. J. Reg. Dev.
Stępniak, M., Rosik, P., 2018. The Role of Transport and Population Components in Change in Accessibility: the Influence of the Distance Decay Parameter. Networks Spat. Econ. 18.
Sveikauskas, L., 1975. The Productivity of Cities.
Thisse, J.-F., 2009. How Transport Costs Shape the Spatial Pattern of Economic Activity.
Vickerman, R., 2018. Can high-speed rail have a transformative effect on the economy?
Vickerman, R., 1996. Location, accessibility and regional development: the appraisal of trans-European networks. Transp. Policy.
Vickerman, R., Spiekermann, K., Wegener, M., 1999. Accessibility and Economic Development in Europe. Reg. Stud.
Wetwitoo, J., Kato, H., 2017. High-speed rail and regional economic productivity through agglomeration and network externality: A case study of inter-regional transportation in Japan.
Witte, P., Oort, F. van, Wiegmans, B., Spit, T., 2014. European Corridors as Carriers of Dynamic Agglomeration Externalities? Eur. Plan. Stud. 22, 2326–2350.
Witte, P., Oort, F. van, Wiegmans, B., Spit, T., 2013. Capitalising on Spatiality in European Transport Corridors. Tijdschr. voor Econ. en Soc. Geogr. 104, 510–517.
Yu, N., Roo, G. de, Jong, M. de, Storm, S., 2016. Does the expansion of a motorway network lead to economic agglomeration? Evidence from China.